CHAPTER 4.
FLOOD RISK REDUCTION STRATEGIES AND TOOLS

This chapter reviews flood risk reduction strategies and tools that will aid King County in meeting the objectives of this Plan. King County's flood risk reduction efforts are centered on five basic strategies:

- Updating, collecting and managing of flood hazard information that is used to direct flood mitigation actions (Section 4.1)
- Management of land uses to prevent the creation of new flood risks and the promotion of flood tolerant land uses in flood hazard areas (Section 4.2)
- Maintenance of river channels (Section 4.3)
- Management of flood protection facilities, including levees, revetments, pump stations and appurtenances (Section 4.4)
- Providing flood hazard education, promoting flood preparedness and improving flood warning and emergency response (Section 4.5)

These strategies are described in the following sections, along with the tools the River and Floodplain Management Program uses to implement or help others implement the strategies. Following a discussion of each strategy are recommendations that describe specific program and project actions that implement the strategies. These actions are not mandatory; they are considered desirable actions that may be completed within staffing and budgetary limitations.

4.1 FLOOD HAZARD INFORMATION

This section summarizes the types of technical information that the River and Floodplain Management Program uses to characterize, quantify, and delineate flood risks. This information is also used to develop and implement strategies and actions to reduce those risks. The types of technical information that can be used to inform flood risk reduction actions include hydrologic and hydraulic studies, floodplain and channel migration zone maps, geologic studies, geographic information system (GIS) land use data, habitat studies, dam operations studies, risk assessments and flood hazard management corridor working maps. To be used effectively, these data need to be managed in a manner that makes them readily accessible and allows new or updated information to be easily integrated.

4.1.1 Flood Hazard Studies and Maps

Technical analyses of watershed hydrology and river channel hydraulics are essential tools for flood hazard management. These analyses provide the information necessary to delineate flood hazard areas, assess and understand flood risks along river reaches, and develop solutions to address those risks. Flood hazard studies and maps are one of the basic components of the flood hazard management corridor described in Section 4.1.3.

Hydrologic and hydraulic analyses are used by floodplain managers, engineers and planners in several ways: they form the basis for flood hazard studies and mapping, which is used for the regulation of existing and proposed floodplain development; they are the analytical tools necessary to evaluate and develop designs for flood hazard management projects; and they can be used to inform watershed and river corridor land-use decisions.

Hydrologic and Hydraulic Modeling Approach

Hydrologic analyses use computer models to estimate the timing and quantity of flow that will run off from storm events in a watershed. The analyses may be completed on a watershed basis or by using river flow data:

- A watershed hydrologic analysis uses data on the watershed's soils, topography and land cover—such as forest, grass, residential development or industrial development—to predict the relationship between precipitation and surface water runoff. Based on these characteristics, the computer model calculates the volume and rate of overland flow to a river or stream. Once the model is calibrated to known or measured data, it can be used to simulate the effect of various watershed conditions, such as increased land development or pre-development forested conditions, and estimate the quantity of flow produced in the watershed for each condition. For floodplain management, the event of most interest is the "base flood," also referred to as the 100-year event. The base flood is the flood event that has a 1-percent chance or probability of occurring in any given year.
- An estimate of the base flood and other flood events, such as the 10-, 50- or 500-year event, can be made by applying a statistical analysis to measured flow data at river gages over an historical period of record (USGS 1982). This type of gage data is collected and published by the U.S. Geologic Survey (USGS) at various points along river and stream systems throughout King County. This method is typically used to compute flood frequencies used in FEMA Flood Insurance Studies and for mapping floodplains shown on FEMA Flood Insurance Rate Maps. These flood frequencies are computed using the period of record available from stream flow gages on the river at the time the study is conducted. Another source of flood frequency data is the USGS, which regularly publishes revised flood frequencies based on the current period of record at each gage. These estimates vary as new data are collected. Recent FEMA floodplain mapping updates in King County have incorporated new hydrologic studies to incorporate longer periods of record from stream flow gages. Older flood studies, which were developed using the period of record available at the time of the study, typically indicate flood frequency flows that differ somewhat from those published more recently by the USGS.

A hydraulic analysis uses the quantity of flow estimated by a hydrologic model to estimate floodwater elevations, depths and velocities along a river channel and its floodplain. The channel and its floodplain are modeled using cross-section data of the river channel and bridge crossings and topographic mapping to characterize floodplain areas. The resistance of ground surfaces to impede the flow of floodwaters through the river channel and its floodplain is simulated by estimating the surface roughness. The roughness parameter characterizes surfaces such as small gravels or large boulders in the river channel and grasses or dense vegetation in the floodplain areas. Model results such as floodwater elevations are cross-checked against observed high water marks from past flood events. Model parameters such as the roughness values can then be adjusted to correlate with the known flood data in order to best represent the expected flood conditions. Flood hazard mapping is produced by plotting the estimated flood elevations generated in the hydraulic analysis onto a topographic map of the river valley.

Uses for Hydrologic and Hydraulic Modeling Results

Flood hazard mapping is most commonly prepared to illustrate the extent of inundation from the 100-year flood event, but it may also include the limits of the 500-year flood event. The 100-year flood standard for floodplain mapping was established by FEMA's National Flood Insurance Program as a minimum standard for regulatory and insurance purposes. This standard, which has been in use for nearly a century, has recently been reexamined by a national forum of floodplain experts. The forum did not recommend any direct changes to or enhancements of the standard (ASFPM 2004).

A hydraulic model can also be used to evaluate changes to flood hazard areas from proposed projects, such as roadways, land development or habitat restoration, by calculating the effect of fill or excavation on the estimated flood elevations. For example, placing fill material in the floodplain can cause a backwater effect upstream, depending on the volume of the fill and its location in the floodplain.

One significant component of a flood hazard analysis is the computation of the floodway area. Under FEMA standards, the floodway is computed by simulating equal amounts of encroachment on each side of the floodplain, moving progressively closer to the center of the channel. This modeled filling of the floodplain is continued until the calculated 100-year water surface elevation rises up to 1 foot. At this point, the outer boundaries of the FEMA Floodway are determined. The floodplain area outside the FEMA floodway is called the flood fringe (see Figure 4-1). The FEMA floodway is typically a pathway of deep, rapidly moving water, and as such it is the most hazardous area within the floodplain. However, more shallow areas of flood waters may also be included in the FEMA floodway.

Federal regulations allow the cumulative encroachment on the floodplain to increase the elevation of the 100-year flood by as much as 1 foot. However, increases of this magnitude can significantly increase flood damage to neighboring properties. Under King County flood hazard regulations, a "zero-rise floodway" is used. The encroachment cannot cause any measurable rise, defined as 0.01 feet, to the 100-year base flood elevation. In this way, backwater effects are prevented. The area outside the zero-rise floodway is called the zero-rise flood fringe (see Figure 4-2).

Computer models also can be used to develop designs for flood hazard management projects. Proposed projects, such as setting back the position of a levee, must be evaluated for their effect on flood elevations to meet federal and county regulatory requirements. A hydraulic model of the existing condition can be modified to reflect the proposed project to determine the impact of proposed modifications on flood elevations, flow velocities and area of expected inundation. This type of analysis is essential to developing effective solutions to flood hazard management risks, not only involving the repair or replacement of existing flood protection facilities, but to inform other floodplain actions such as modifications to road approaches and bridge structures. Hydraulic models are also used to assess the effectiveness of proposed gravel removal projects on reducing flood elevations. Section 4.3.1 provides further information on sediment monitoring and gravel removal evaluations.

Hydrologic models can be used to evaluate the impacts of land-use changes in a watershed, serving as an important tool in land-use planning and zoning decisions. For example, a hydrologic model can be used to predict the impact of converting an area from forest cover to residential development on the timing and volume of downstream surface water runoff. This application of a hydrologic analysis is typically applied to urbanizing stream basins to evaluate what would happen to stream flows if the basin were "built out" at allowable densities. The computed stream flows can then be input to the hydraulic model to determine the future-conditions floodplain—the floodplain that can be expected after buildout. This analysis can help direct decision-making on upland land uses or the development of capital projects to mitigate predicted increases in runoff and floodplain area.

Figure 4-1

FEMA FLOODPLAIN AND FLOODWAY

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN

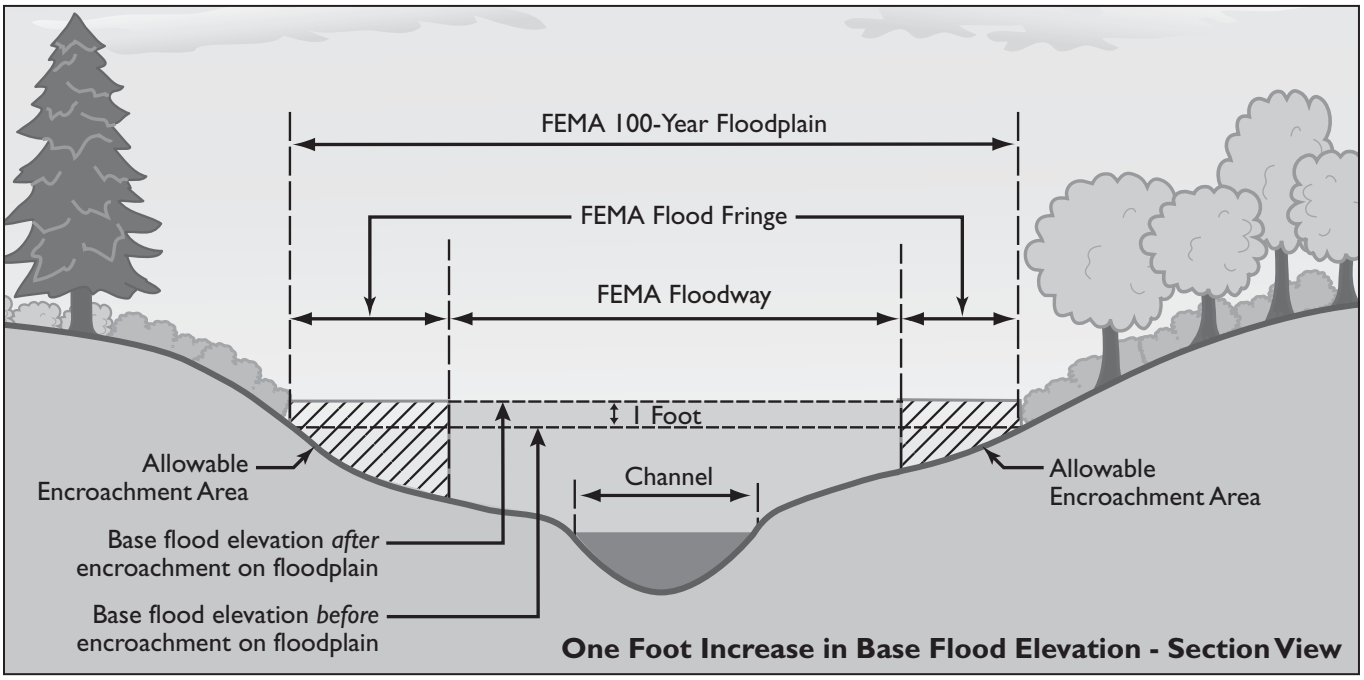
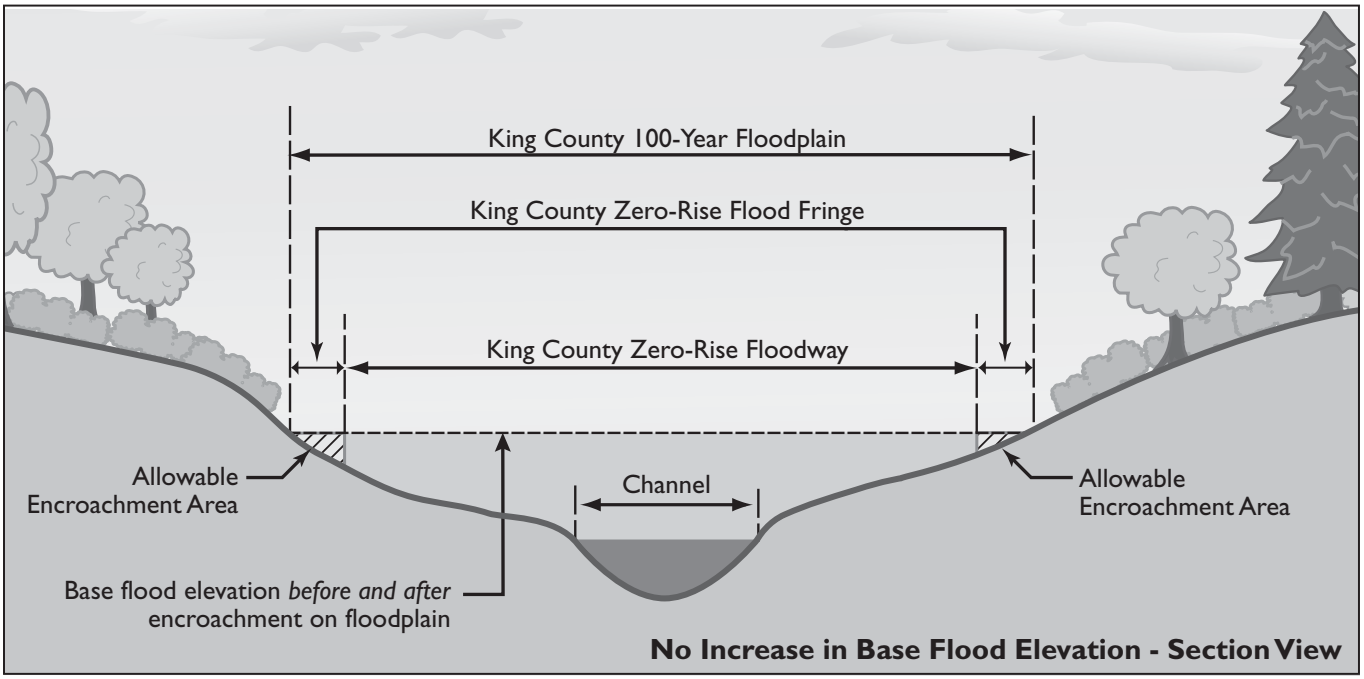


Figure 4-2

KING COUNTY ZERO-RISE FLOODPLAIN AND FLOODWAY

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG41_42.ai wgab

Map Modernization Program

King County regulations are applied using FEMA's 100-year floodplain and floodway; but FEMA maps are based on current or historical land use, and land use conditions can change, causing the rate and volume of runoff to increase. When this happens, the 100-year floodplain expands and flood depths increase, inundating properties not currently mapped in the FEMA floodplain. Moreover, research on climate change indicates that precipitation, temperature and snow levels are changing over time. Hydrologic and hydraulic analyses can evaluate how land use and climate changes affect river flooding.

Federal funding for FEMA has been inadequate to carry out studies needed for unmapped areas or for updates to existing flood studies. King County and local jurisdictions have stepped forward with local support to complete new studies, but the updating of hazard maps for major rivers, streams, lakes and marine shorelines is heavily dependent on federal support.

To address the national need to update flood studies and maps, FEMA issued the report, *Modernizing FEMA's Flood Hazard Mapping Program*, which laid the groundwork for the Map Modernization Program currently in progress (FEMA 1997). Based in part on this report and an implementing strategy (FEMA 2002a), the U.S. Congress appropriated initial funding to support the Map Modernization Program in fiscal year 2003 and has continued to provide annual appropriations of nearly $200 million.

The Map Modernization Program set goals to reduce the age of flood maps, produce digital mapping for high priority areas, develop flood maps for many previously unmapped communities and encourage states and communities to share the costs of flood mapping. Cost-sharing is achieved through FEMA's Cooperating Technical Partner Program (FEMA 2002a and FEMA 2005a), which incorporates communities' local knowledge into the mapping, resulting in more accurate and representative information. King County joined the Cooperating Technical Partner program in September 2001.

Previous Flood Studies and Mapping

Floodplain studies and flood hazard area mapping have been produced since the late 1960s. The quality of the studies is directly dependent on the quality of the base data used. In many cases, data on historical river flows, channel cross-section surveys and topographic mapping has been limited, lacking in detail, or out of date due to changed river conditions:

- Limited Availability of Gage Data—Gage records are used to predict flood and precipitation frequency, which is the likelihood of a given level of rainfall or flooding occurring in a given year. Although the gage record may span a relatively short time period, it can be extrapolated statistically to estimate the size of events that have not actually been measured, such as the 100-year flood. The longer the period of record for the gage, the more accurate the estimate of these large flood events. Estimates of the 100-year flood flow can vary as new data are collected and added to the period of record.
- Minimal Data Collection—Computer models require a certain amount of information to adequately simulate watershed, river channel and floodplain characteristics. Without adequate information, it is difficult to calibrate the model, and its accuracy is questionable.
- Changes in Physical Conditions—Even if all the data input to a model are accurate and complete, the physical conditions represented by those data can change over time. Channels may change location through lateral migration. They may increase or decrease in size as sediment is transported through the river system. Land cover may be converted from forests to developed areas of grass and impervious surfaces. As these physical characteristics change, the original model becomes less representative of current conditions.

The 1993 *Flood Hazard Reduction Plan* documented the hydrologic and hydraulic models that were available at the time for the major river systems in King County, including an assessment of the quality of data used. Improving flood hazard data and mapping has been a high priority since then, and King County has completed several flood studies. Table 4-1 lists the flood studies completed since 1993. To date, most of the completed flood study updates are in the South Fork Skykomish and Snoqualmie River basins. A Cedar River flood study has also been completed but FEMA has yet to publish the study and maps. For each of these studies, new aerial photography, topographic mapping, river channel cross-section data, and hydrologic and hydraulic analyses were used to provide the best available technical information following FEMA's technical guidelines (FEMA 2003).

It should be noted that King County does not wait for FEMA to reflect the impacts of these flood studies in physical map revisions to regulate development based on this information. King County regulates new development based on the best available data. This includes data King County has developed that exceeds FEMA standards, such as basin plans that use future conditions hydrology.

King County's initial project under FEMA's Cooperating Technical Partner Program was the completion of the Upper Snoqualmie flood study in the North Bend area for the Middle and South Forks of the Snoqualmie River. Subsequently, the King County River and Floodplain Management Program received full federal support through the Map Modernization program to update the lower Snoqualmie River flood study. The 1993 *Flood Hazard Reduction Plan* had identified the update to the lower Snoqualmie River flood study as a significant mapping need. In September 2003, FEMA provided a Cooperating Technical Partner grant to King County to conduct a new flood study for this area. King County is coordinating this work in collaboration with Snohomish County, which also participates in the Cooperating Technical Partner Program. In addition to the 34 miles of the lower Snoqualmie River and nearly 9 miles of Patterson Creek in King County, the flood study includes the 6 miles of the Snoqualmie River and over 8 miles of the Skykomish River in Snohomish County.

Future Needs

Although a significant number of flood studies have been completed, further effort is needed to update the remaining major river studies in King County:

- Green River—On portions of the Green River, survey data is over 30 years old, cross-sections are spaced over a mile apart and the contour interval of the topographic maps is up to 5 feet. In some reaches of the river, the channel has laterally migrated since the data for the existing flood study was collected. Major commercial, industrial and residential developments, situated behind levee systems in the lower reach, have occurred throughout the basin since the floodplain maps were produced. A new flood study for the Green River from River Mile 5 to River Mile 45 was initiated in early 2006 and is partially funded with a grant from the Washington State Department of Ecology.
- White River—All of the White River in King County is in need of a flood study. Pierce County recently updated the reach below River Mile 5. The existing flood study for the King County portions of the White River used cross-section data collected in 1974. Because the White River is a sediment-rich system with deposition occurring in the lower reaches, it is unlikely that the existing flood study is representative of current day hazards. The location of the channel is different in some areas from what the existing flood mapping shows, and there are large areas of the floodplain for which flood mapping has yet to be completed. For example, at least one home in the Red Creek area is in the direct path of high-velocity flood flows but is not in an area mapped as such. The Flood Insurance Rate Map also is inaccurate in that it shows Red Creek entering the White River upstream of where it actually does. These inaccuracies do not allow for appropriate floodplain regulation in these areas.

TABLE 4-1.
FLOOD STUDIES COMPLETED BY KING COUNTY SINCE 1993.

River	Study Reach (Length in river miles)	Hydrologic Period of Record	Date of Physical Base Data	Date Submitted to FEMA	Date of Effective FIRM
Raging River	Mouth to upstream of I-90 bridge (5.5 miles)	1946 - 1992	1993 aerials, topographic map and channel survey	December 20, 1993	May 20, 1996
Middle Fork Snoqualmie River	Mt Si Bridge to 3.5 miles above the bridge (3.5 miles)	Three gages: 1961 - 1992; 1909 -1992; 1962 - 1978	1993 aerials, topographic map and channel survey	May 8, 1995	March 30, 1998
South Fork Skykomish River	Snohomish-King County Line to Tye-Foss confluence (13 miles)	1897 - 1982	1993 aerials, topographic map and channel survey	June 12, 1995	March 30, 1998
North Fork Snoqualmie River and Tate Creek	Mouth to 2.4 miles upstream (2.4 miles plus 1 mile for Tate Creek)	Two gages: 1909 - 1978; 1930 - 1992	1995 aerials, topographic map and channel survey	March 1, 1996	March 30, 1998
Tolt River	Mouth to 6.0 miles upstream (6 miles)	1929 through 1993	1994 aerials, topographic map and channel survey	March 10, 1997	December 6, 2001 and May 1, 2002
South Fork Snoqualmie River	I-90 bridge to above Edgewick Road bridge (5 miles)	1909 - 1990;	1995 aerials, topographic map and channel survey	April 14, 1997	December 6, 2001
Upper Snoqualmie (North Bend area)	Mouth of the South Fork to I-90 bridge and Middle Fork to Mt Si bridge (total approx. 7 miles)	Same as for the North, Middle and South Fork Snoqualmie studies	1993 and 1995 aerials, topographic maps and channel surveys	USCOE 1998; Appealed twice and resubmitted in 2001 and 2003	April 19, 2005
Cedar River	Elliot Bridge to Landsburg (17 miles)	Two gages: 1946 - 1999; 1920 - 1999	1999 aerials and 1999+2000 topographic maps and channel surveys	December 2002 Technically approved by FEMA in 2003.	Preliminary Flood Insurance Rate Map due in 2006
Lower Snoqualmie River	Snohomish County line to Snoqualmie Falls (34 miles)	1930 - 2004	2004 aerials, topographic maps and channel survey	May 2006	Preliminary Flood Insurance Rate Map due in 2006
Patterson Creek	Mouth to upstream crossing of SR 202 (approx. 9 miles)	Three gages: 1991-2005 1991-2005 1991-205	2004 aerials and topographic maps and 2005 channel survey	Scheduled for July 2006	Preliminary Flood Insurance Rate Map due in 2007

- Greenwater River—This is a major tributary to the White River. The Greenwater River has only an approximate flood zone defined, which provides no information on flood elevations or a delineated floodway. A detailed flood study is needed along the lowermost portion of the river where a riverside residential community is located.
- Sammamish River—Survey data for the Sammamish River dates from 1965. Extensive urban development in the basin has altered flows and sediment loads entering from tributaries. The contour interval used for these existing flood maps is 5 feet rather than the more detailed interval of 2 feet. A 2-foot interval greatly improves the mapping accuracy of flood hazard boundaries. The insurance analysis performed in the Risk Assessment for this Plan (Appendix C) supports the need for mapping by identifying that 71 percent of the flood insurance policies in force within the basin are outside the mapped 100-year floodplain.

In addition to mainstem rivers and their larger tributaries, numerous streams, lakes and marine shoreline are in need of current flood hazard information. FEMA has updated some of the flood studies for streams in King County, such as Bear and Evans Creeks, using information developed as part of the basin plans for these watersheds. Cities have also been working to update flood studies for streams in incorporated areas, such as Issaquah Creek in Issaquah and Springbrook Creek and the lower Cedar River in Renton. The FEMA study for King County does not have any detailed flood height information for Vashon-Maury Island or the Puget Sound shoreline; such information would significantly update King County's flood hazard information and is included as a county-wide recommendation in the Action Plan in Appendix F.

King County closely collaborates with the Washington State Department of Ecology to complete flood study updates (Ecology 2004); the upcoming flood study for the Green River is being supported by Ecology funding, and King County routinely coordinates all other studies with Ecology staff. Ecology has received Map Modernization funding to initiate work in 2005 to revise all of the flood hazard maps in unincorporated and incorporated areas of King County into an enhanced digital format called the Digital Flood Insurance Rate Map. This is a GIS format that includes direct linkage of base data such as cross-section information and survey benchmarks with the flood hazard maps. All of the river flood studies completed by King County since 1993 and more recent efforts on the Cedar and Snoqualmie Rivers and Springbrook Creek will be included in this conversion in late 2006.

Recommendations

- **MAP-1**—Flood studies should be completed for the remaining mainstem rivers (Green, White, Greenwater and Sammamish) and be used to update FEMA flood insurance studies and rate maps.
- **MAP-2**—King County should maintain the best available flood study information and any supporting data for use in the implementation of flood hazard management programs, policies, and regulations.
- **MAP-3**—King County should periodically evaluate the need for flood study updates depending on changes in channel and floodplain conditions, changes in watershed hydrology or any significant changes in dam operations. If any new information suggests that available flood study analyses are in error—for example, if a major flood reveals differences between floodplain maps and actual flood hazard conditions—an update to the existing study should be initiated.
- **MAP-4**—King County should notify FEMA and Ecology that a revision to the flood study and maps is needed when inaccuracies are identified or if hydrologic and hydraulic characteristics have significantly changed, making existing mapping outdated.

- **MAP-5**—King County should continue to participate in the Cooperating Technical Partner Program with FEMA to leverage funding, strengthen inter-jurisdictional partnerships with cities, and maximize federal, state and local funding opportunities through grant application submittals for the completion of new and revised FEMA Flood Insurance Studies and Flood Insurance Rate Maps.
- **MAP-6**—King County should investigate in future flood study updates the potential for including a flood hazard zone reflecting future conditions on the FIRM when requested by a community.
- **MAP-7—**As a Cooperating Technical Partner, King County should evaluate the feasibility of participating with FEMA to leverage funding for small streams and marine shoreline studies and maps.

4.1.2 Geologic Studies and Maps

Geologic studies and maps provide information that is essential to understanding flood hazards and reducing the risks associated with these hazards. The geology and soils in a watershed profoundly affect the hydrology, hydraulics and morphology of the river. The type and distribution of soils and underlying geology determine how precipitation will travel through surface and ground water systems. These factors also influence the amount and size of sediments entering a channel, which in turn influence the stability of the channel itself. Thus, any comprehensive effort to understand a river system, its flooding and erosion hazards, and the viability of flood risk reduction actions, should include geologic analyses. Geologic studies that are important to flood risk reduction include soils maps, sediment studies, geomorphic studies of channel reaches and basins, and channel migration studies. The type of geologic study that is most critical to flood risk reduction is the channel migration study.

King County experiences two major types of hazards associated with flooding: inundation and channel migration. Floodplain maps show inundation areas, but these areas do not necessarily correspond to areas at risk due to channel migration. For example, as shown in Figure 4-3, a house may be on a high bank, above the 100-year flood elevation, yet be endangered by the river eroding the ground beneath it. Channel migration studies produce maps that show the likely extent and severity of channel migration.

Channel Migration Practices

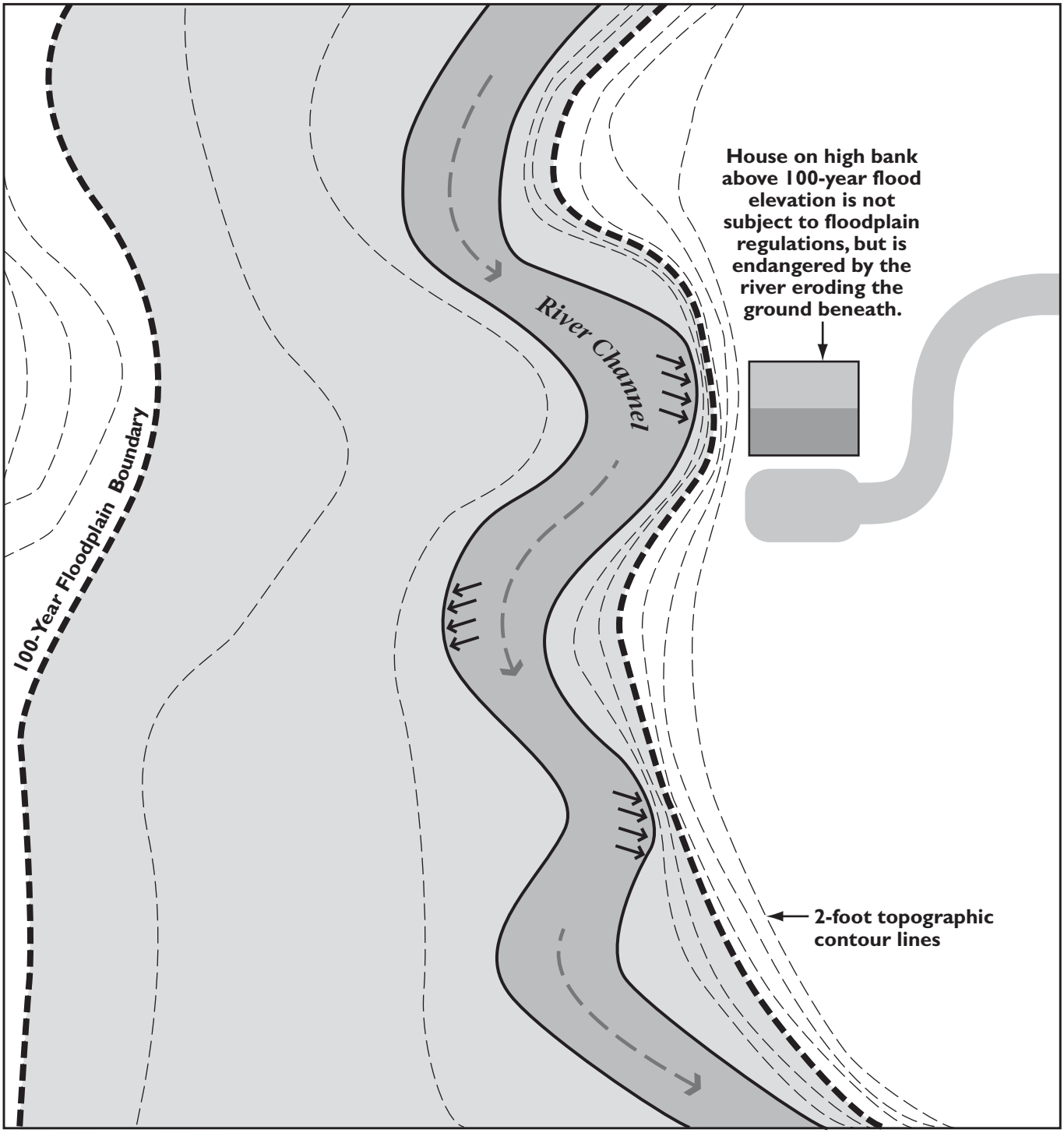
King County's historical response to channel migration was construction and maintenance of levees and revetments to fortify banks and prevent migration. In recent years, King County has invested considerable resources in maintaining flood protection facilities built in the past. These flood protection facilities remain subject to damage and even failure. In at least one case in recent history, a private residence was destroyed after a King County flood protection facility failed.

Because of the risks to public safety and the high cost and regulatory restrictions associated with construction and maintenance of flood protection facilities, the current flood hazard management approach is to direct new development away from channel migration hazard areas. Channel migration hazard area mapping and the adoption of land-use regulations to limit development in these areas provide the starting point for preventing future risks and in some cases reducing existing risks associated with migrating river channels. Additionally, the inherent value of allowing natural river processes to create and reshape fish and wildlife habitat is now also widely recognized. A major emphasis of salmon habitat recovery plans is to restore floodplains and allow natural rates and magnitudes of channel migration.

Figure 4-3

CHANNEL MIGRATION IMPACTS ON PROPERTIES OUTSIDE THE FLOODPLAIN

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG43.ai wgab

The *Snoqualmie Valley Community Plan* adopted in 1989 and the 1993 *Flood Hazard Reduction Plan* included policy direction calling for the identification of channel migration hazard areas and the adoption of land use regulations to preclude unsafe development in these hazard areas. Since 1991, channel migration zones have been mapped along 49 miles of King County rivers. These maps delineate both severe and moderate channel migration hazard areas within the overall channel migration zone. The severe channel migration hazard area is a portion of the channel migration zone that has a total width equal to 100 years times the average annual channel migration rate, plus the present channel width. The moderate channel migration hazard area is the portion of the channel migration zone that lies between the severe channel migration hazard area and the outer boundary of the channel migration zone. The methods by which the outer boundary of the channel migration zone is mapped include consideration of historical channel locations and historical meander bend dimensions. Details on channel migration zone mapping methods are described in the technical report that is prepared as the basis of each channel migration zone map. In 1999, a King County public rule on channel migration was enacted to prohibit certain development and regulate other development within channel migration zones in order to reduce unsafe land uses.

Existing Channel Migration Studies in King County

King County has studied and mapped channel migration zones along four of its major rivers: the lower Tolt River from River Mile 1.7 to River Mile 6.0; the Three Forks of the Snoqualmie River, including the lower parts of the South, Middle, and North Forks; the Raging River from River Mile 1.5 to River Mile 9.0; and the middle Green River from River Mile 25 to River Mile 46. In preparing these studies and maps, King County used historical channel locations, geology, basin hydrology, riverbank materials, current channel conditions, abandoned channels and potential avulsion sites, channel migration rates, existing infrastructure, and professional judgment to characterize the channel migration zones. Study findings were used to map both severe and moderate channel migration hazard areas. An example of a channel migration zone mapped along the middle Green River is shown in Figure 4-4.

Future Needs

The primary future need is to continue to map channel migration hazards along other large King County rivers. Channel migration zone mapping is in progress on the Cedar River from Landsburg (River Mile 22.5) downstream to Renton (about River Mile 3), the White River from Mud Mountain Dam (River Mile 29.5) downstream to the County Line (River Mile 5), and the South Fork Skykomish River from the Foss River confluence (River Mile 19.9) downstream to the County Line (River Mile 6.4). Completion of channel migration hazard mapping along these three rivers is the highest priority for the remaining large King County rivers. Channel migration hazard mapping also is needed for the White River upstream of Mud Mountain Dam and along the lower Greenwater River. Channel migration hazard mapping also may be considered for specific segments on other King County rivers, as warranted.

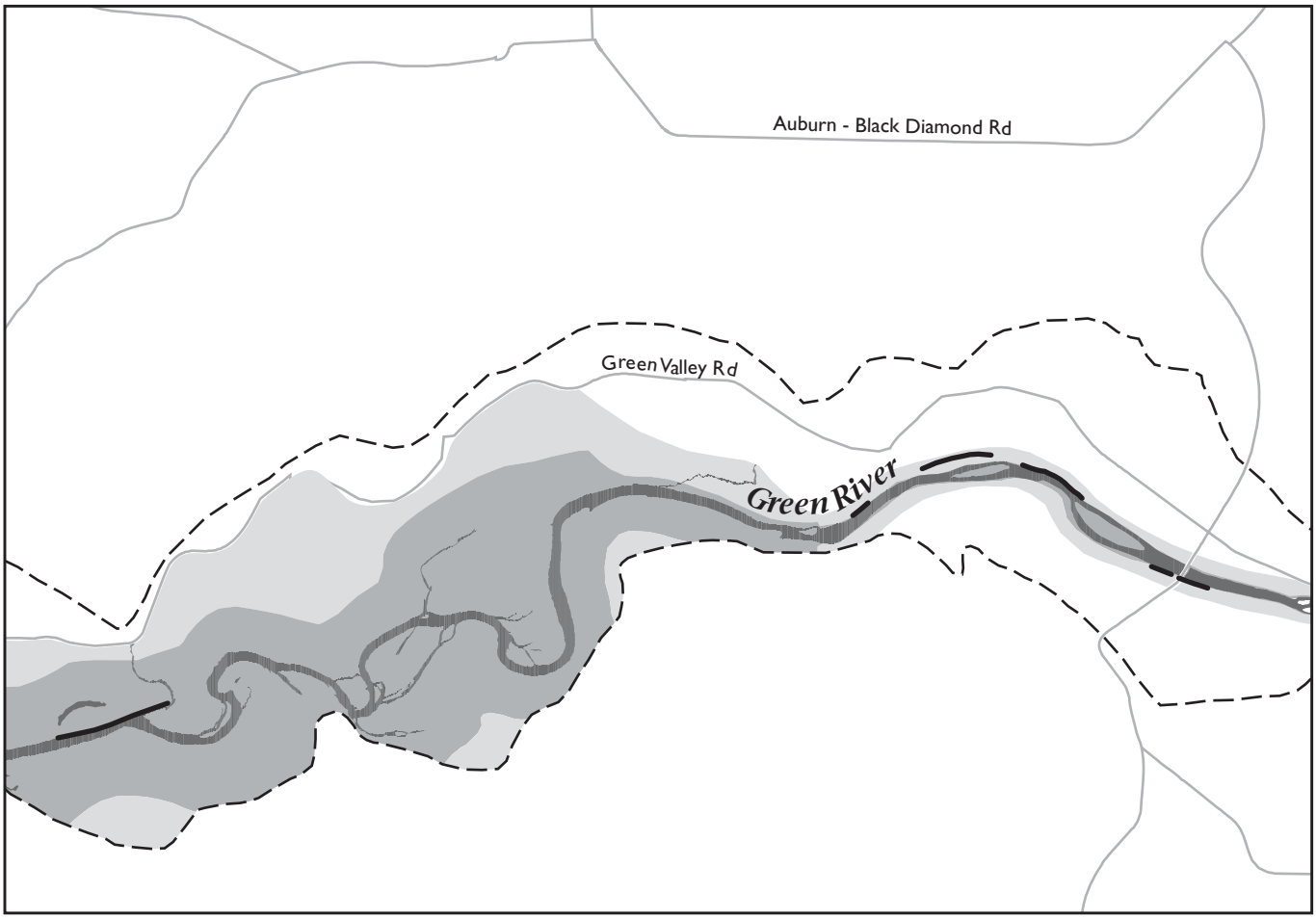
Recommendations

- **CMZ-1**—King County should complete channel migration hazard mapping on the Cedar River, White River and South Fork Skykomish River.
- **CMZ-2**—King County should map channel migration hazards along the White River upstream of Mud Mountain Dam and the lower Greenwater River.
- **CMZ-3**—King County should map channel migration hazards along other river segments, as warranted.

Figure 4-4

GREEN RIVER CHANNEL MIGRATION HAZARD MAP (excerpt)

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG44.ai wgab

Channel Location

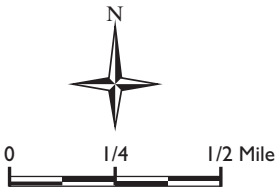
Severe Hazard Area

Moderate Hazard Area

Levees and Revetments

Valley Wall

Roads



4.1.3 Flood Hazard Management Corridor

The flood hazard management corridor is the area of a river and surrounding lands that is essential to the storage and conveyance of floodwaters and integral to natural riverine processes. The principal flood hazard management goal for these areas is the reduction or elimination of flood-related risks in a manner that supports other beneficial riparian uses and reduces long-term flood hazard management costs.

Flood hazard management corridors are defined using a data compilation process. Existing mapped flood hazard areas, regulated critical areas in unincorporated King County, and other existing information relating to rivers and flood conditions are combined as composite flood hazard management corridor working maps. These working maps can be a valuable tool for improving communication between the agencies and entities active within flood hazards areas and riparian corridors. Additional information can be overlaid on the working maps to assist in coordinating with other programs and objectives, such as recovery of threatened or endangered species.

Flood Hazard Management Corridor Working Maps

Flood hazard management corridor working maps were developed for the South Fork Skykomish, Snoqualmie, Tolt, Raging, Cedar, Sammamish, Green, White and Greenwater Rivers. Data sets used to develop these working maps include aerial photography, mapped floodplains and floodways, mapped severe and moderate channel migration hazard areas, regulated aquatic and wetland buffers, and landslide hazard areas and buffers adjacent to mainstem rivers. Areas of known or potential deep and fast flows and areas of potential levee failure, based on observations and anecdotal documentation, were included as available. Side-channels and the lower reaches of tributaries that interact hydraulically with the mainstem rivers were also included. Data for some of these working maps is incomplete since not all rivers have mapped channel migration zones and the quality of floodplain maps varies. Updating these corridor working maps as new data becomes available is essential to effective use of this tool.

Floodplain and floodway delineations used in the corridor working maps were based on the current-condition 100-year flood, as mapped according to FEMA standards. These may include FEMA's published Flood Insurance Rate Maps or best available flood study maps. Mapped channel migration zones, aquatic area and wetland buffers, and landslide hazard areas and buffers reflect the delineations regulated by the King County Critical Areas Ordinance. Where channel migration zones have not been mapped, information on historical channel locations and Light Detection and Ranging (LiDAR) data were used to develop preliminary channel migration zone data. The limited landslide hazard area mapping in the Critical Areas Ordinance was supplemented with information from studies of topographic features and observed landslide occurrences.

In addition to these mapped and regulated features, known or projected hazard areas were identified and included on the working maps. Areas of deep and fast flows have been observed during past storm events or documented through public inquires or complaints, post-flood damage assessments and flood protection facility inspections. These sources of information, along with an analysis of floodplain topography, were used to predict areas outside the mapped floodway that may nonetheless be subject to deep fast flows.

Areas of potential levee failure are critical but not well understood as hazard areas in King County. Determining the risk associated with potential levee failures requires information on the structural integrity of the levees, the depth and velocity of flow that would occur if the levee were to fail, and an understanding of what would be damaged by deep fast flows near the levee failure and by standing water in the formerly-protected area. Information needed to accurately assess the risks associated with potential levee failures is one of the more critical data gaps in the current flood hazard management corridor

mapping efforts. Preliminary delineations for potential levee failure were prepared based primarily on topography.

Hence the flood hazard management corridor is that area along a river in which any one of its component mapped hazard areas, or other associated critical area, exists. The boundary of the flood hazard management corridor runs along the outer boundary of the hazard area or other critical area that extends the greatest distance from the river. Places within the corridor that are located within overlapping individual component hazard areas may be inferred to have a relatively higher inherent flood hazard; places within the corridor that are located within only one of the component hazard area may be inferred to have relatively lower inherent flood hazard. Table 4-2 summarizes the data used in developing the flood hazard management corridor working maps for this Plan. Figure 4-5 shows a typical flood hazard management corridor working map.

In this way, the flood hazard management corridor working maps use a compilation of mapped flooding and channel migration and other associated hazards to illustrate the gradation of hazards on the landscape and allow an assessment of the extent and severity of flood hazards in a particular location. By overlaying this composite of hazard layers on aerial photographs, one can identify what structures and properties appear to be at risk and estimate the severity of the risk. The working maps were initially used to identify areas at risk from flooding and erosion hazards. The degree of risk depicted on the working maps was then used to help prioritize the projects included in the 10-Year Action Plan in Appendix F.

Recommendations

- **COR-1**—Complete hazard area mapping needed to fill data gaps in flood hazard management corridor working maps.
- **COR-2**—Complete risk assessments of King County flood protection facilities so that areas of potential levee failure can be more accurately characterized on flood hazard management corridor working maps.
- **COR-3**— Incorporate state-of-the-art approaches to information management, for spatial and non-spatial data sets, to ensure that the flood hazard management corridor working maps can be efficiently updated to reflect new information or changed conditions.
- **COR-4—**Investigate the feasibility of modeling flood hazard management corridors to evaluate the cumulative effect of proposed flood risk reduction actions and other land use actions so future actions can be modified through adaptive management techniques.
- **COR-5—**Update flood hazard management corridor working maps as flood hazard, land use and ecological data sets are improved.
- **COR-6—**Evaluate and document the impact of flood hazard management actions on flood risk and on beneficial uses of the flood hazard management corridor.

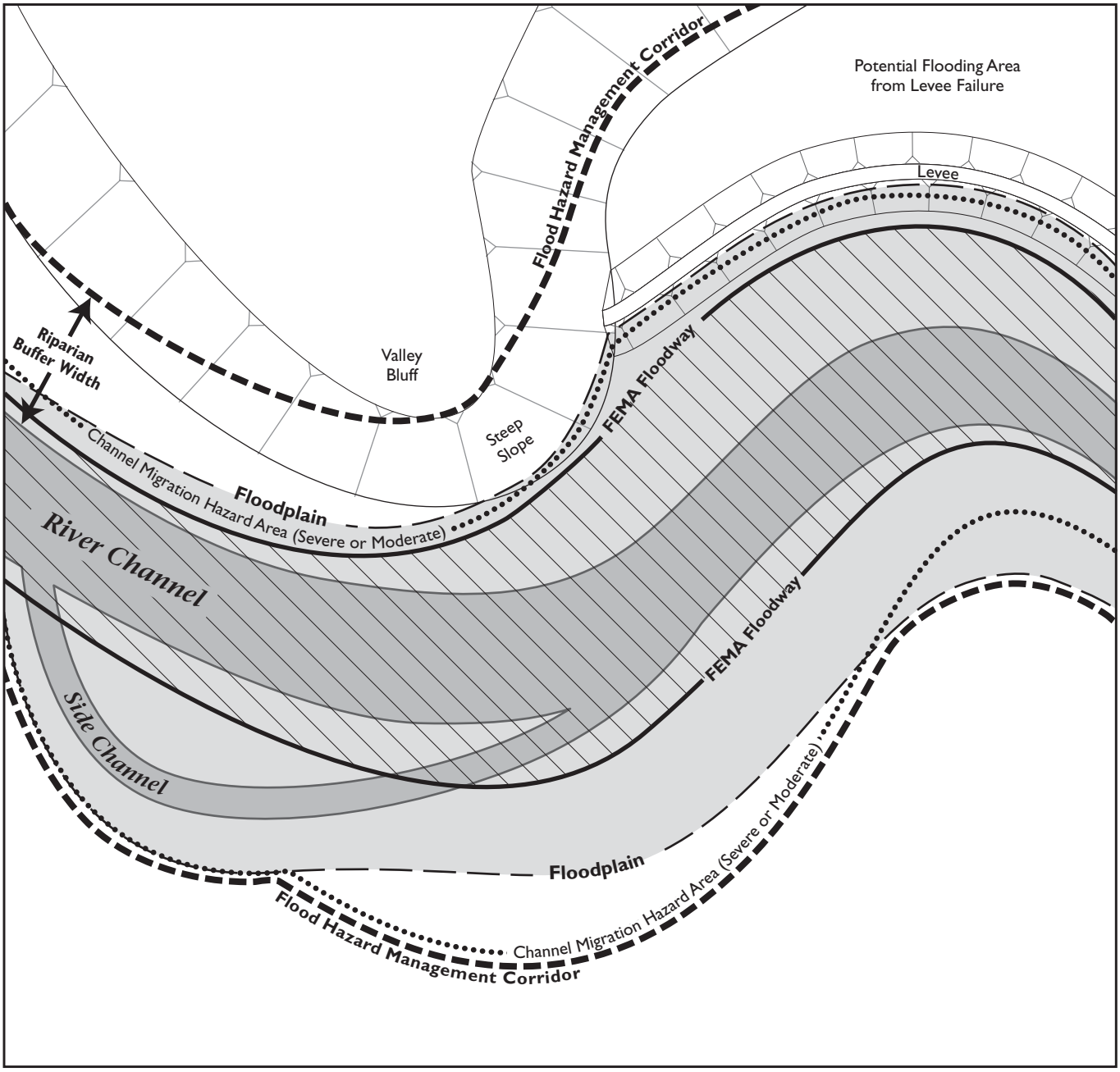
TABLE 4-2.
FLOOD HAZARD CORRIDOR WORKING MAP REACHES AND DATA AVAILABILITY FOR KING COUNTY RIVERS

River	Reach Length Description	River Mile	Floodplain Map	FEMA Floodway	Channel Migration Zone Map
South Fork Skykomish River	King-Snohomish County line to the confluence of the Tye and Foss Rivers	6.4 to 19.9	Yes	Yes	In Progress
Lower Snoqualmie River	King-Snohomish County line to the base of Snoqualmie Falls	5.9 to 40.0	Yes; Update in Progress	Yes; Update in Progress	No
Tolt River	Confluence with the Snoqualmie River to River Mile 6	0 to 6.0	Yes	Yes	Yes
Raging River	Confluence with the Snoqualmie River to River Mile 9	0 to 9.0	Yes	Yes	Yes
Upper Snoqualmie River	Snoqualmie Falls to the Middle and North Fork confluence	40.0 to 44.0	Yes	Yes	Yes
North Fork Snoqualmie River	Confluence with the Snoqualmie River to River Mile 1.9	0 to 1.9	Yes	Yes	Yes
Middle Fork Snoqualmie River	Confluence with the North Fork to River Mile 49	0.0 to 5.0	Yes	Yes	Yes
South Fork Snoqualmie River	Confluence with the Snoqualmie River to River Mile 6.5	0 to 6.5	Yes	Yes	Yes
Cedar River	Lake Washington to River Mile 22.1 near Landsburg Road	0 to 22.1	Yes	Yes	In Progress
Sammamish River	Lake Washington to Lake Sammamish	0 to 13.5	Yes	Yes	No
Green River	Duwamish River near Boeing Access Road to Flaming Geyser State Park	5.5 to 44.7	Yes	Yes	Yes, for River Mile 25.5 to 45.2
White River	King-Pierce County line to Mud Mountain Dam	5.5 to 29.6	Yes, for River Mile 5.5 to 40.5	Yes, for River Mile 6.3 to 8.8	In Progress
Greenwater River	Confluence with the White River to River Mile 1.0	0 to 1.0	No	No	No

Figure 4-5

SCHEMATIC PLAN VIEW OF A TYPICAL FLOOD HAZARD MANAGEMENT CORRIDOR *WORKING MAP*

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG45.ai wgab

River/Side Channel

Floodplain

FEMA Floodway

Flood Hazard Management Corridor

Channel Migration Hazard Area (Severe or Moderate)

4.2 MANAGEMENT OF LAND USES

The most effective way to reduce costs and risks in flood hazard areas is to maximize human activities and land uses that are compatible with flooding and minimize those that are not. Land uses and associated human activity and behavior that put people and property at risk from flood-related hazards can include residential and commercial development, operation of critical facilities, and roads that serve as sole or emergency transportation routes. Land uses more likely to be flood tolerant include agriculture and forestry, non-critical transportation routes, passive recreation and open space.

This section describes ways that King County, and more specifically, the River and Floodplain Management Program, can encourage more flood tolerant land uses in flood hazard areas in unincorporated areas. The primary tools available for this include:

- Development and implementation of regulations to prevent new or expanded development in high risk areas in unincorporated areas,
- Provision of technical information and assistance to private citizens and public entities, and
- Capital projects and acquisitions that eliminate or reduce the extent of existing at-risk development or prevent the creation of new at-risk development.

4.2.1 Flood Hazard Areas Regulations

Regulation of land uses in flood hazard areas can be one of the most effective ways of reducing the risk from flooding and channel migration. The King County Surface Water Design Manual and the International Building Codes adopted and amended by King County establish regulations for development in flood hazard areas. However, the vast majority of King County's flood hazard area regulations for unincorporated areas are in the Critical Areas Ordinance, which was adopted in 2004 and is codified in King County Code Chapter 21A.24. The Washington State Growth Management Act requires that "frequently flooded areas" be protected. Frequently flooded areas, as defined in the Act are the same as "flood hazard areas" as defined by King County. Inclusion of flood hazard areas in the Critical Areas Ordinance helps qualify unincorporated King County for participation in the National Flood Insurance Program, which is coordinated by the Washington State Department of Ecology and is intended to:

- Provide federally subsidized flood insurance for property owners
- Reduce flood damage to new construction
- Minimize future flood damage to existing structures.

Familiarity with the terms used in the King County Code is important for understanding King County's flood hazard regulations. King County has established standards beyond the federal requirements and developed specific regulatory areas. In King County, the following are considered flood hazard areas:

- Floodplain
- Zero-rise flood fringe
- Zero-rise floodway
- FEMA floodway
- Channel migration zones.

King County delineates flood hazard areas using base flood elevations and a wide variety of flood hazard data for a flood having a 1-percent chance of being equaled or exceeded in any given year. The base

flood is often referred to as the "100-year flood." The base flood is generally determined using existing conditions unless a King County-approved basin plan or hydrologic study has been completed using projected flows for future conditions.

Many flood hazard areas are mapped in FEMA's *The Flood Insurance Study for King County and Incorporated Areas*. However when there are multiple sources of flood hazard data, King County uses the following available data to determine a flood hazard area:

- FEMA Flood insurance rate maps
- FEMA Flood insurance studies
- FEMA Preliminary flood insurance rate maps
- FEMA Preliminary flood insurance studies
- Draft flood boundary work maps and associated technical reports
- Critical areas reports prepared in accordance with the FEMA standards and the *King County Surface Water Design Manual*
- FEMA Letter of map amendments
- FEMA Letter of map revisions
- Channel migration zone maps and studies
- Private site specific studies
- Historical flood hazard information
- Wind and wave data provided by the U.S. Army Corps of Engineers.

Development Within the Zero-Rise Flood Fringe, Zero-Rise Floodway and FEMA Floodway

The zero-rise flood fringe is the area of the floodplain outside of the zero-rise floodway that is associated with standing water during flood events rather than rapidly flowing water. Since this area presents less risk than other portions of the floodplain, some development is allowed, as long as it conforms to standards stipulated by the code. The zero-rise floodway includes the channel of a stream or river and that portion of the adjoining floodplain that is necessary to discharge the base flood. The phrase "zero-rise" means that King County regulations prohibit any development that will result in any measurable rise in the base flood elevation. Measurable rise is defined in code as 0.01 feet, which can be determined through hydraulic modeling. The FEMA floodway includes the channel of a stream or river and the adjoining floodplain that is necessary to contain and discharge the base flood without increasing the base flood elevation more than 1 foot. The FEMA floodway is a portion of the zero-rise floodway, which is larger.

Key standards for development within the zero-rise flood fringe in unincorporated King County include the following:

- Compensatory storage is required.
- Development is not allowed if the depth is more than 3 feet or the velocity is more than 3 feet per second.
- New lots need at least 5,000 square feet outside the zero-rise floodway.
- Utilities must be flood-proofed and are allowed only if no reasonable alternative is available.

- The lowest floor for residences must be elevated at least 1 foot above the base flood elevation. Non-residential structures must be elevated at least 1 foot above base flood elevation or be flood-proofed.
- Foundations must contain openings to allow floodwaters to enter and exit.
- Flood-resistant materials are required.
- Post and piling techniques are required, but alternatives may be considered.
- All structures must be anchored.
- Critical facilities are allowed only in certain portions of the floodplain and must be elevated 3 feet above the base flood elevation or to the 500-year elevation, whichever is greater.

Key standards for development within the zero-rise floodway include the following:

- The standards that apply to the zero-rise flood fringe also apply in the zero-rise floodway.
- No rise in the base flood elevation is allowed unless state and federal requirements are met and all affected property owners agree.
- Temporary structures and hazardous materials must be removed from the floodplain during the flood season, which is from September 30 through May 1 of each year.
- Critical facilities are not allowed except for structures that are dependent on being located in the zero-rise floodway, including, but not limited to bridge piers, bank stabilization structures and dams.
- Livestock flood sanctuaries and manure storage facilities are reviewed through a farm plan.

Key standards for development within the FEMA floodway include the following:

- The standards that apply to the zero-rise flood fringe and zero-rise floodway also apply in the FEMA floodway.
- No rise in the base flood elevation is allowed.
- New residences and nonresidential structures are prohibited in the FEMA floodway.
- Maintenance, repair, and replacement of existing farmhouses, substantially damaged existing residential structures and historic structures in the FEMA floodway are allowed if they meet certain standards.
- Livestock flood sanctuaries and manure storage facilities are not allowed in the FEMA floodway.

Development Within Channel Migration Zones

King County has mapped a number of channel migration zones. The maps and the process used to designate and classify channel migration zones are specified in a public rule adopted by the King County Department of Development and Environmental Services. A channel migration zone consists of the river channel, the severe channel migration hazard area and the moderate channel migration hazard area.

Key standards for development within moderate channel migration hazard area in unincorporated King County include:

- Allowed uses must be located in the area that is least subject to risk from channel migration.

- Maintenance, repair, modification, or additions to existing structures are allowed if the footprint is not expanded toward the source of channel migration.
- New dwellings on pre-1995 lots are allowed under certain circumstances.
- New accessory structures are allowed under certain circumstances.
- When subdividing property, each lot must contain at least 5,000 square feet outside of the moderate channel migration hazard area and all lots must have safe access routes to the lot.
- Infrastructure for new lots must be outside the moderate channel migration hazard area, except septic systems, which are allowed under certain circumstances.

Key provisions in the severe channel migration hazard area include:

- Development is limited to structures that do not house humans or animals.
- New public infrastructure is discouraged.

Agricultural Structures in the FEMA Floodway

Agricultural lands in King County are often located within the broad, flat floodplains along the lower reaches of King County's major rivers. These agricultural lands are protected under the Growth Management Act and the King County Comprehensive Plan. Individual farms may include land in the floodplain, including the FEMA floodway. While repairing substantially damaged residential structures is allowed in the FEMA floodway under state and King County regulations, current King County regulations restrict the construction of new residential and non-residential structures in the FEMA floodway in unincorporated areas. However, it may be reasonable to allow temporary or flood resistant agricultural structures in the FEMA floodway if they are compatible with King County regulations related to compensatory storage, the King County and FEMA zero rise floodway prohibitions (0.01 feet and 0.00 feet, respectively), and other floodplain regulations.

Appendix B of this Plan provides a more detailed description of federal, state and local regulations that apply within flood hazard areas.

Recommendations

- **REG-1**—King County should evaluate the need to develop land use regulations for development in marine shoreline flooding areas.
- **REG-2**—King County should evaluate regulatory standards under future planning mechanisms to determine if code amendments will increase the level of flood protection for new development that is permitted within the floodplain.
- **REG-3**—King County should work with federal, state and local agencies, the agricultural community, and other stakeholders to determine the effects of allowing agricultural structures to be built in the FEMA floodway in unincorporated King County. After this analysis is completed, King County should evaluate whether the code should be amended.
- **REG-4**—King County should assess the need to amend the King County Code flood hazard regulations to require a Notice on Title alerting property owners that their property is not mapped as a flood hazard area because they are protected by a levee, which has the potential to fail.

4.2.2 Technical Assistance and Consultation

The River and Floodplain Management Program can help public and private entities make wise land use decisions to reduce flood-related risks with a range of technical assistance and consultation: by sharing

expertise in hazard identification techniques; by interpreting flood hazard data, maps, and regulations; and by reviewing and coordinating planning and design efforts by public and private entities that overlap, impact or are impacted by flood hazard areas. The River and Floodplain Management Program has considerable technical information and expertise about regional flood-related hazards, yet current resource limitations have minimized the degree to which the program actively pursues this strategy.

Flood Hazard Identification

King County has worked closely with FEMA and engineering consultants to expand the coverage and improve the accuracy of flood-related studies and maps that delineate flood hazards along many of the major rivers and tributaries in King County. Techniques and protocols have been developed and refined for mapping channel migration hazard areas, floodplains, and floodways. Sharing this knowledge with other jurisdictions in King County can reduce the overall public cost of these efforts and improve consistency in the management of flood hazards throughout the different jurisdictions. Flood-related studies and maps are located at most King County regional libraries and on the King County web site. In addition, the Department of Natural Resources and Parks and the Department of Development and Environmental Services maintain copies of these maps and studies.

Review and Coordination in Areas of "Common Interest" (or "Overlapping Uses")

Many land uses occur in flood hazard areas, with varying degrees of compatibility. For some uses, such as roads and bridges, overlap with flood hazard areas is common and sometimes unavoidable. Residential and commercial development is another common use that affects and is affected by flood hazards. Other uses, such as agriculture or open space, can be compatible with, and even benefit from, proximity to flood hazard areas. Still other uses, such as aquatic and riparian habitat for fish and wildlife, are often located in flood hazard areas. Participation and coordination in the planning and design of these overlapping uses in flood hazard areas will help maximize overall public benefits in the most cost-effective manner, and will provide for the greatest level of public safety.

Roads and Bridges

River valleys can offer a continuous pathway of consistent gradient, and many roads are built adjacent to and paralleling rivers. When the roads are built too close, the natural process of bank erosion or channel migration can undermine the road, requiring extensive fortification of the banks and ongoing maintenance. This pattern is already evident in many locations. In addition to needing constant repairs, the flood protection facilities installed to protect the road tend to damage valuable aquatic and riparian habitat. Repairs to these flood protection facilities or construction of new facilities should be reviewed for impacts related to flood and aquatic and riparian habitat, and mitigation should be considered to prevent future damage. Mitigation could involve changes to the alignment of the road or the design and construction techniques used to build and maintain it.

Similarly, the approaches of bridges crossing rivers can often span a floodplain. This presents two common problems. First, the bridges themselves can be an obstacle to flood conveyance and a barrier to the passage of debris transported during floods. This can increase flooding and even lead to washouts of bridges and approach roads. Second, the approach is often built on a prism of fill intended to prevent the approach road from being overtopped during flood events. However, more often than not, this prism blocks flood conveyance down the valley and increases backwater elevations. Designs of road and bridge improvement projects can be reviewed, and technical assistance can be provided to help design for flood conveyance, changes in channel conditions and bridge clearance requirements.

Residential and Commercial Development

Structures in a floodplain put people and properties at risk. Nonetheless, many structures already exist in the floodplain, and new development may still occur in flood hazard areas where permissible. Because these developments affect the people who use them and also may affect upstream and downstream properties and ecosystem functions, it is important that new or improved structures be designed to minimize flood risk while protecting other important uses of the corridor. Technical assistance to private property owners can include review of new development proposals, response to inquiries about potential flood hazards on specific parcels, site visits, and guidance concerning the design of privately constructed bank stabilization projects.

Agriculture, Recreation and Open Space

Agriculture, recreation and open space are uses that can be compatible with flood hazard areas and often even beneficial in the management of flooding. They contain fewer structures at risk from flooding and often help maintain the flood storage and flow conveyance capacity of floodplains.

Inundation by floodwaters is common on many farms and in many cases can be tolerated as part of the natural seasonal pattern of farm activity. Flooding often supplies nutrient-rich silt that replenishes the valuable topsoil essential to farming. On the other hand, areas susceptible to high velocity flows, or prone to river and stream channel migration, can experience erosion that leaves farms vulnerable to infrastructure damage or severe loss of acreage, and possibly loss of farm viability. As farming is an important regional value that is protected through a variety of means in King County, it is important that the needs of the farm be balanced with flood hazard management activities and capabilities.

Many parks in flood hazard areas experience occasional flooding, which can cause a temporary disruption or inconvenience. These areas serve an important flood hazard mitigation function by providing a relatively safe place for the water to go. However, some recreational infrastructure poses a potential conflict with flooding. Portions of the regional trail system are built on top of pre-existing flood protection facilities. These flood protection facilities may be prone to more frequent damage than if they were located further from the river channel, and will likely encumber future flood protection facility retrofit. Alternatively, flood hazard management projects can have an effect on adjacent and neighboring recreational areas. Coordination among departments and agencies on lands containing both recreation and flood hazards can lead to well-designed projects that meet both needs.

Open space lands are important in their own right and provide opportunities for many other valued activities. As a stand-alone use, open space areas provide flood storage and conveyance and still offer passive recreation, aesthetic enjoyment, riparian vegetation, and preservation and enhancement of aquatic and riparian habitat. When considered as part of a corridor, they can be essential links in a network of parcels within a larger project to reduce flood risk or improve habitat. One of the more significant values may be their role in restoration of habitat for the recovery of threatened or endangered species.

Recommendations

- **TECH-1**—The River and Floodplain Management Program should expand and formalize its current efforts to provide information, technical assistance and consultations to help public and private entities make wise land use decisions that reduce or eliminate flood-related risks.
- **TECH-2**—The River and Floodplain Management Program should document all technical assistance and consultation efforts to allow follow-up after flood events to evaluate the degree to which these efforts can reduce or prevent the creation of new, flood-related risks.
- **TECH-3**—The River and Floodplain Management Program should continue to work with those involved in the use and management of agricultural, recreational and open space lands

in flood hazard management corridors, to ensure that land uses remain compatible with the natural conveyance of floodwaters.

- **TECH-4**—The River and Floodplain Management Program should participate in assessment, design, and repair of roads, bridges, regional trails and other infrastructure that may experience frequent inundation or erosion, through coordination with the appropriate agencies. Flood conditions and flood hazard management project recommendations should be considered along with other programs' objectives when selecting acquisition targets and establishing management strategies for open spaces.
- **TECH-5**—Flood hazard management corridor objectives should be used to inform the project design and construction methods associated with repair or improvements to bridges, roads and regional trails.
- **TECH-6**—The River and Floodplain Management Program should participate in salmon habitat recovery and other fish and wildlife habitat enhancement projects to ensure that flood-related risks associated with these projects are avoided or minimized.

4.2.3 Home Elevations, Relocations, Acquisitions and Land Management

Elevation, relocation and acquisition of structures, and acquisition and management of undeveloped land in flood-prone areas are all effective means of reducing or preventing risks to structures and their occupants without constructing or upgrading flood protection facilities. Relocation and acquisition projects provide permanent and complete protection from flood and channel migration hazards; elevation projects provide long-term risk reduction benefits, but do not completely eliminate the risk. In addition, elevation projects may not be the best solution in areas with deep or fast flow, heavy debris loads, or other considerations such as high habitat restoration needs. The level of involvement and investment by the River and Floodplain Management Program ranges from complete funding, using only dedicated program funds, to securing grants for projects in which some or all of the matching funds are provided by the property owner. Except under very limited circumstances, elevation, relocation, and acquisition projects are voluntary on the part of property owners.

These projects have gained wider use in recent years as a result of their proven effectiveness, multiple benefits, and increasing acceptance, and even pursuit, by the public. They can provide long-term cost savings by reducing flood insurance claims, eliminating the need for flood protection facilities and reducing public expenditures for flood warning and emergency response. In many cases, these projects allow floodplain and channel migration areas to be reconnected to the river, providing improved habitat and ecosystem restoration opportunities.

Elevation

Elevation projects involve raising the finished floor of a structure so that it is above the 100-year flood elevation such that it is compliant with federal, state and county regulations. The first habitable floor must be raised at least one foot above the 100-year flood elevation, or three feet above the 100-year flood elevation if the structure is a critical facility. Elevation projects are appropriate in areas where structures are subjected to ponded or low-velocity floodwaters. While elevation of the structure does not completely remove the flood risk, it can significantly curtail damage to the structure and the accompanying disruption to its occupants. Elevation projects are not, however, a viable alternative in areas subject to high-velocity flows, bank erosion or channel avulsion hazards, as the structures would remain within a high risk area, and be subject to stranding or undermining and collapse.

Elevation projects are completed by private contractors through agreements with the individual property owner. The construction process from groundbreaking to completion is generally six to eight weeks, and in some cases the structure can be occupied during construction. The River and Floodplain Management Program has assisted with home elevations by securing, administering, and passing along to the property owner, grants and loans from federal, state, and local hazard mitigation and housing assistance programs.

Home elevation projects can reduce recurring flood damage while allowing property owners to remain in their homes, thereby preserving neighborhoods and historic buildings and avoiding added pressure on housing resources. They can also reduce flood insurance rates for property owners. Because flood risk is reduced, elevation projects tend to reduce federally backed insurance claim payments, emergency response service expenses, and the costs of constructing and maintaining flood protection facilities. They may also accommodate modest improvements in flood storage and conveyance.

Relocation

A relocation project moves a heavily damaged or at-risk structure to a new location outside the flood hazard area. The structure is stabilized, removed from its existing foundation, transported to a new location outside the flood hazard area, and secured onto a new foundation. The new location may be a safe building site on another portion of the same property or a different property. If the structure is relocated to a different property, the original site may be acquired by King County for permanent open space. The opportunity to relocate homes and their occupants is dependent upon such conditions as the desire of the occupants to keep their home, the availability of an appropriate new location for the structure, and the feasibility of moving the structure.

Relocation projects can greatly reduce future flood damage while allowing property owners to remain in their homes and possibly on their property. As a relocation project completely removes the home from the flood hazard area, flood protection facility construction and maintenance, flood insurance, flood warning, and emergency response services are no longer needed. Flood storage and conveyance can be dramatically improved, benefiting neighboring properties and public facilities. Relocations also create an opportunity to enhance or restore fish and wildlife habitat on the flood-prone portion of the property and in some cases, provide public access to the shoreline.

Acquisition

Three types of acquisition projects may be useful for flood hazard management:

- Flood Buyouts—In a typical flood buyout project, an entire flood-prone parcel is acquired through a fee-simple purchase from a willing property owner. The occupants move to a new location, all structures on the site are demolished, the site is restored, and the lands are maintained as open space in perpetuity. Buyout projects permanently separate people from the flood hazards affecting them and their property. All flood risks and the costs associated with flood damage prevention, mitigation, and repairs are eliminated. Federal and state grant and disaster assistance programs often provide funding to cover a percentage of the cost of the initial purchase and site modifications. Long-term maintenance and associated land management obligations typically remain with King County.
- Open Space Acquisitions in Flood Hazard Areas—Undeveloped properties in flood hazard areas may be targeted for acquisition where they are at risk of being developed. While flood hazard regulations limit development in flood hazard areas, they fall short of outright prohibition. New development in flood hazard areas, while permissible, may have costly consequences in terms of safety and damage if for example, flood conditions change or were not correctly identified. Open space acquisitions are distinguished from home buyouts in that they are often proactive rather than reactive; home buyouts result in the removal of at-risk

structures, while open space acquisitions can prevent flood intolerant land uses from occurring.

- Acquisition of Lands for Flood Risk Reduction Projects—Partial or full interest in lands that lie within a planned flood risk reduction project area may be necessary in order to implement the project. The design of the project, the specific site, and the potential flood impacts on the land would determine the exact nature of the land interest that is needed.

Acquisitions provide opportunities to increase flood storage and conveyance, to reconnect the river with its floodplain and to restore natural river processes. In addition to the flood risk reduction benefits, preserving or returning lands to open space use can help create an inter-connected network of lands that support a variety of other beneficial uses, including habitat, water quality, recreation, aesthetic enhancements, and interpretive sites and trails. Acquisitions also provide valuable riparian lands that may be used for subsequent flood-compatible projects, such as site restoration to support recovery of threatened or endangered species or repair damaged habitat. Acquisition projects can be accomplished through varying degrees of property interests:

- Fee-simple land purchase generally involves a voluntary and mutually satisfactory negotiated settlement between the property owner and King County based on appraised fair market value. While most fee-simple acquisitions are negotiated directly with private parties, some properties become available for purchase at auction when property taxes are delinquent for a period of greater than two years.
- Acquisition of a partial property interest can include purchase of certain future development rights across the entire parcel or purchase of river protection or conservation easements across a specific portion of the property. This could allow a property to serve both private and public uses simultaneously with adherence to specific rules and limitations.
- Donations may be offered by private individuals who no longer wish to maintain ownership of a parcel, but should only be agreed upon if the parcel meets the River and Floodplain Management Program's acquisition objectives and criteria.
- Condemnation is when real property is acquired through the use of eminent domain authorities, and is an acquisition strategy of last resort when a mutually satisfactory negotiated settlement cannot be reached on a parcel essential to a planned flood risk reduction project.

Flood corridor property acquisitions are typically funded through state or federal grants that result in deed restrictions that limit future land uses on the property to those that are flood tolerant. Property interests acquired for flood risk reduction purposes can complement other public and privately held open space lands, which together can contribute to the establishment of a low risk, multiple use flood hazard management corridor.

Property Management

The River and Floodplain Management Program maintains lands acquired within the flood hazard management corridor, currently totaling over 413 acres. Ideally, these properties are managed in a manner that maximizes public benefits beyond those directly related to flood risk reduction. However, declining funding has limited the opportunity for the program to provide potential public benefits such as restoration of aquatic and riparian habitat or creation and maintenance of public access to rivers for recreation and aesthetic uses. The River and Floodplain Management Program also manages an extensive inventory of River Protection Easements. However, in most cases, King County's rights granted by these easements are limited to carrying out work directly related to the construction and maintenance flood protection facilities.

Active management of flood hazard management corridor properties has included mowing, noxious weed eradication, trash removal, prevention of unauthorized access and vandalism, and in some cases revegetation. Passive uses such as walking, fishing, bird watching, swimming, and launching of non-motorized watercraft are the most appropriate use of these lands, and have become more common in recent years. Management of these lands will aim to ensure that public uses do not degrade the use for others or the habitat value of these lands. Coordination with other programs and agencies will support uses or improvements to these lands that provide open space conservation, viewshed protection, improvements to water quality and aquatic and riparian habitat, and when appropriate, public access opportunities on flood hazard management properties and other nearby public lands.

Recommendations

- **ERA-1**—King County should identify properties that are potential candidates for elevation, relocation or buyout projects based on an evaluation of the flood risks, project feasibility, and planned flood risk reduction capital projects. The department should prepare a list of targeted high priority acquisitions, annually update this list and distribute it to interested agencies. An example of a high priority project would be a property identified by FEMA as a repetitive loss property.
- **ERA-2**—King County should conduct outreach to the property owners to alert them to the flood risks; inform them about potential opportunities for elevation, relocation, or buyout; and assess their interest in participation should funding be available. Property owners who are interested in participating in one of these programs should be informed that having flood insurance may help qualify them for funding assistance.
- **ERA-3**—King County and FEMA should co-sponsor free public workshops to educate citizens about elevation projects. These workshops should include representatives from the King County Department of Development and Environmental Services who can provide prospective owners with detailed information on needed permits and the process required for King County approvals.
- **ERA-4**—King County should continue to assist private property owners in home elevation, relocation, and flood buyout projects where they are an appropriate means of reducing flood risk. King County should continue to assist in securing funds for these projects through federal, state, and local programs.
- **ERA-5**—The River and Floodplain Management Program should develop and implement site management guidelines for each of its jurisdictional lands and improve documentation of its property interests to ensure that site-specific property rights and associated deed restrictions are readily available.
- **ERA-6**—King County Department of Natural Resources and Parks should coordinate with other programs and agencies to share information about property ownership in flood hazard management corridor areas in order to achieve cross-programmatic maintenance and resource management goals and objectives, such as restoring floodplain habitats for meeting salmon habitat recovery plan goals.

4.3 RIVER CHANNEL MAINTENANCE

River channels provide for the conveyance of flood flows. The accumulation of sediment and large woody debris in river channels through natural river processes can create an impediment to flood flow conveyance, sometimes redirecting flows in a way that increases flood-related risks. Modifying the river channel to improve or redirect flood conveyance is one tool that King County may employ selectively to reduce flood risks.

While alteration of sediment and large woody debris may provide an effective flood risk reduction measure in some instances, it is generally only a temporary solution that must be repeated in order to maintain its effectiveness. This can make in-channel maintenance costly over time. Also, adverse impacts on other ecosystem functions, most notably aquatic habitat conditions, could occur. King County policies provide guidance regarding the application of these channel maintenance actions. The following sections provide background information and recommendations for future actions.

4.3.1 Sediment Management

Sediment management can involve actions that alter the distribution of sediment within a channel to accommodate or redirect flows or actions that alter the corridor within which the channel flows in order to accommodate the natural movement and deposition of sediment. Sound sediment management is dependent upon monitoring the channel where sediment is accumulating in order to understand how these accumulations are likely to affect local flood conditions. These two components—channel monitoring and sediment management actions—are the two main components of an overall sediment management program.

When steep channels and tributaries meet broad, low-gradient, valleys, flow velocities decrease and the ability of the river to move sediment is reduced. This reduced ability to move sediment results in the deposition of sand and gravel in the channel. Under natural conditions, an unconfined river channel can move horizontally or "migrate" to accommodate flow around the deposited sediment. In rivers that are confined by levees or revetments, however, the channel cannot migrate. Deposition of sediment in armored reaches can decrease flood capacity through the reach, which may result in increased flooding and erosion of the bank armoring. As these armored reaches were typically built to protect an adjacent land use, the effects of sediment accumulation can lead to an increased flood risk.

While the movement of sediment creates dynamic channel conditions that may lead to localized impacts on flood risks, this natural geomorphic process also creates diverse instream habitat conditions that are beneficial to fish and wildlife. Therefore, careful consideration must be given to any action to alter this process. Strategies to manage the accumulation of sediment as it affects flooding in King County's rivers are described below.

Channel Monitoring

In order to consider various flood risk reduction strategies and determine the best strategy, information on sediment accumulation and its effect on channel capacity is needed. Changes in channel morphology can be tracked over time in order to identify trends in sediment movement and potential flood risks that may be associated with those changes. By monitoring sediment levels in a channel, changes in effectiveness of adjacent flood protection facilities, such as the containment capacity of a levee system, can be identified and evaluated. This information can also provide a useful tool in estimating the amount of flood risk reduction benefits that would result from gravel removal or other constructed channel modifications and the life expectancy of those benefits.

Survey methods are typically used to characterize sediment levels relative to the bank top. One or more cross-sections—lines generally running perpendicular to the direction of flow—are surveyed. The survey is repeated at the same location after a time (one to several years), and changes in gravel surface elevations are compared. This comparison allows sediment accretion or scour during the intervening period to be characterized. In some cases, survey data may be collected at densities adequate to prepare a topographic map of the channel bottom, which provides more information than individual cross-sections.

A comprehensive effort to monitor the effect of sediment accumulation on flood water levels would use the most current survey data to hydraulically model the resulting water surface elevations. Ideally, an

existing hydraulic model, for example, from a completed flood study, could be modified by inserting the most recently surveyed cross-section data to determine if there have been any significant alterations in flood water levels due to sediment accumulation since the previous survey. The combination of current survey data and hydraulic modeling of associated water levels can be used to document the effect of sediment accumulation on flooding in the affected river reach.

To date, a number of actions have been taken toward establishment of a channel monitoring system on King County's rivers. Cross-sections have been surveyed in certain river reaches along King County-maintained levees and revetments, particularly where large volumes of sediment accumulation occur near developed areas. The main sources of surveyed cross-sections have been recent flood studies and monitoring efforts specifically meant to characterize sediment levels in areas of known concern. Primary areas of known concern for sedimentation that have been surveyed periodically by King County are the lower Tolt River near the City of Carnation, the lower Raging River, the South Fork Snoqualmie River in North Bend, parts of the mainstem Snoqualmie River near Fall City and Carnation, and parts of the lower White River in the Cities of Auburn and Pacific. The City of Renton conducts its own sediment monitoring program for the lower 2 miles of the Cedar River. The City of Auburn surveys cross-sections in a 1.25-mile stretch of the White River.

King County has surveyed cross-sections periodically in areas of known concern for about the last 10 years and has collected survey data collected by others for previous periods, some of which date back to the 1960s. This collection of survey data constitutes the foundation of a channel monitoring program. Changes in sediment levels over time at individual cross-sections and cumulatively through a reach have been calculated for some locations. However, survey data for all of the different areas of concern have not been organized in a single coordinated database. Data surveyed earlier than 1990 can be difficult to retrieve and use. Field monumentation and site survey control varies among the different surveyed reaches. Hydraulic modeling, which can be used to characterize changes in water surface elevation associated with changes in sediment levels, has not yet been conducted in all reaches where cross-sections have been surveyed.

Sediment Management Actions, Including Gravel Removal

Once channel monitoring documents that sediment accumulation is a direct cause of increased flood hazard and flood risk, informed actions to decrease the flood risks can be identified, evaluated, and implemented. Any permanent solution to flood risks related to sediment accumulation will probably involve altering the existing bank armoring, removing structures that are at risk from the flood hazard area, or both. Potential permanent solutions include levee set backs, floodplain reconnections, buyouts of affected structures, or a combination thereof. These permanent capital alternatives are described in greater detail in Section 4.4.3.

Gravel removal is another potential flood reduction action. Although river sediments can include a full range of sizes such as silt and sand to gravel and cobble, the term "gravel" is commonly used to refer to all sediment accumulation and "gravel removal" to its excavation. Gravel removal includes gravel bar scalping, which is excavating the top of the portion of a gravel bar above the ordinary water level, and dredging, which is excavating the full channel width including gravel bars and the wetted channel. Gravel removal does not provide a permanent remedy in an area of ongoing sedimentation. It must be repeated to maintain its effectiveness as new sediments replace those that have been removed. Therefore, depending on the rate of accretion, gravel removal may not be cost-effective as a flood risk reduction strategy over the long term.

Historically, King County conducted gravel removal operations for flood risk reduction in a number of channels, including the Snoqualmie River near Carnation, the lower Tolt and Raging Rivers, and parts of

the White River. The City of Renton has an ongoing gravel removal project to meet the goal of maintaining 100-year containment along the lower Cedar River. Most gravel removal operations conducted by King County for flood reduction purposes were discontinued in the late 1960s to early 1970s as funding from flood control bonds dwindled and as a result of the growing recognition of the environmental impacts of in-channel dredging. Since that time, a significant body of research has documented the adverse effects of gravel removal on aquatic and riparian habitat and a set of guidelines for gravel removal in areas of freshwater salmonid habitat was recently published (NMFS 2004; Kondolf et. al. 2001; NOAA 2004). Additionally, the 1999 listing of Puget Sound Chinook salmon and bull trout as threatened under the Endangered Species Act, and the recent revisions to the *Washington State Shoreline Master Plan Guidelines* may further limit gravel removal operations. Furthermore, some salmon habitat recovery plans completed since the 1993 *Flood Hazard Reduction Plan* call for gravel augmentation projects to augment or replenish spawning gravels in certain parts of King County rivers. Although gravel augmentation generally would occur in a different location than an area of accretion, any gravel removal proposal would need to consider and be coordinated with existing or proposed gravel augmentation projects.

While both the Endangered Species Act and the Shoreline Master Plan may constrain gravel removal or prevent specific operations, neither places an outright prohibition on gravel removal for flood risk reduction. Although there are potential adverse impacts of gravel removal, and the longevity of its flood benefits may be limited, there still may be cases in which gravel removal should be considered as a flood risk reduction strategy. If gravel removal is to occur, specific methods should be used and specific issues should be addressed, as recommended in contemporary documents and guidelines (NMFS 2004; Collins et.al. 1990; NOAA 2004).

The River and Floodplain Management Program can provide direction for gravel removal actions by performing the work directly or by providing technical data and analyses for use by others seeking to conduct gravel removal in King County.

Sediment Management Program

The dynamic nature of sediment moving through a river system makes sediment management a process that requires an assessment of conditions, the evaluation and selection of appropriate actions, the monitoring of results, and ultimately the adaptation of the process based on the findings of the monitoring. The first step in this process is to establish a specific goal for flood risk reduction or prevention. This goal can be expressed as a flood threshold beyond which there is an unacceptable flood risk. Exceedance of the threshold would trigger a sediment management action for flood risk reduction. Choosing a course of action in response to sediment accumulation that poses a flood risk involves identifying potential action alternatives, analyzing their long-term flood reduction benefits as well as potential adverse effects, and evaluating each alternative relative to the identified flood risk reduction goal and other evaluation criteria such as cost effectiveness. Alternatives that meet the identified flood risk reduction goal and evaluation criteria can then be considered for implementation relative to other flood hazard management projects and priorities. Figure 4-6 illustrates how channel monitoring and alternative analyses can be used to identify appropriate sediment management actions and determine the effectiveness of these actions on an ongoing basis.

Recommendations

- **SED-1**—The existing channel monitoring program should be continued and enhanced with clearly defined objectives, geographic locations, priorities, monitoring frequency, and reach-specific purposes for those channels monitored by King County. Channel monitoring should be funded at a level that ensures that the locations of sediment accumulations are identified,

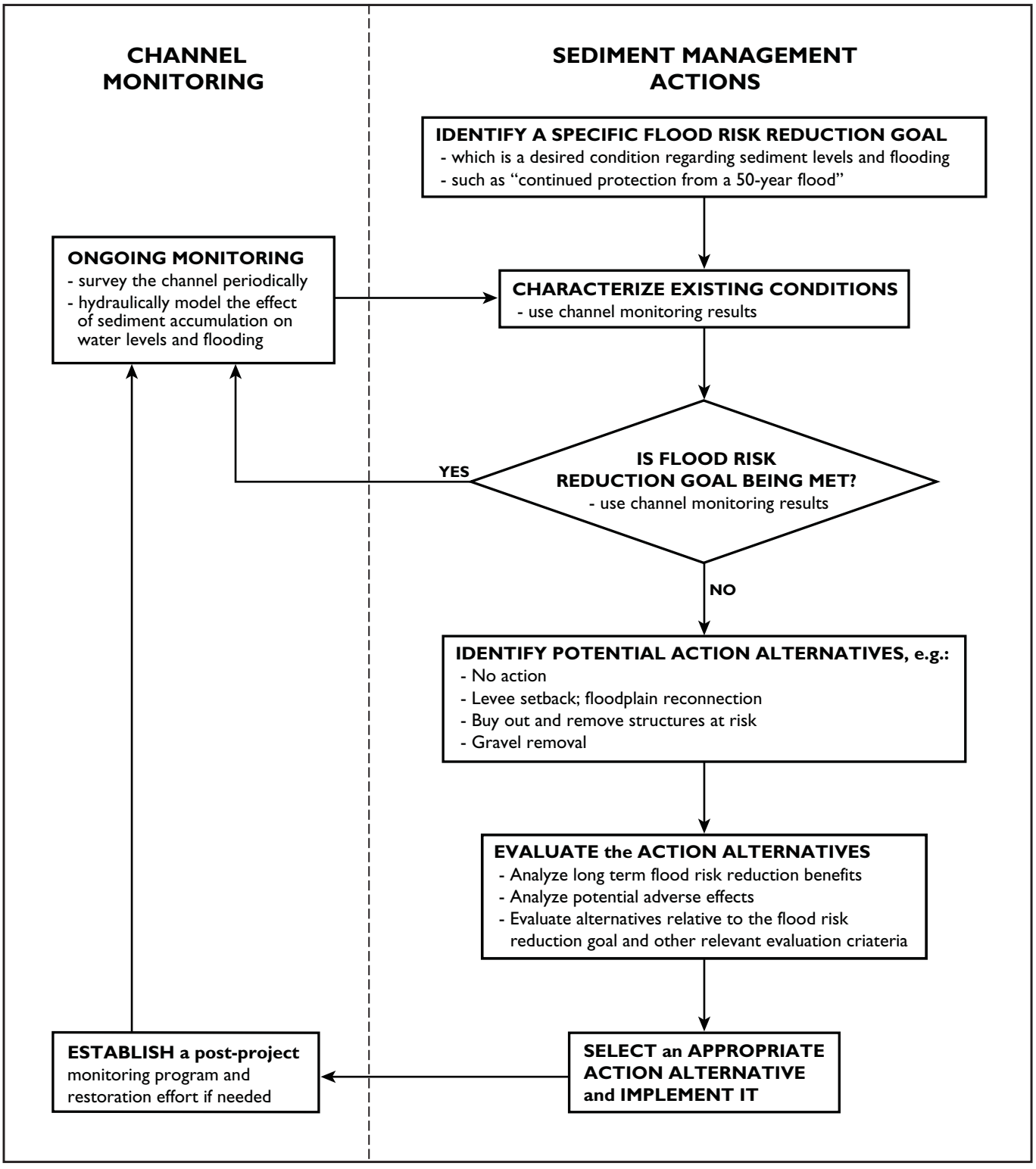
that changes in sediment volume are understood, and that the effects of sediment accumulations on channel capacity and flood risks can be characterized.

- **SED-2**—A sediment management program (per Figure 4-6) should be applied to all of the channels monitored by King County, with actions that include: establishing a flood risk threshold that would trigger action; evaluating potential actions if channel monitoring reveals that the risk threshold is exceeded due to sediment accumulation; and implementing an appropriate action that meets the established flood risk reduction goal and other relevant evaluation criteria. The sediment management program should be funded adequately to meet sediment management goals.
- **SED-3**—King County should continue to consider conducting gravel removal projects for flood risk reduction purposes on a case-by-case basis, based on information gathered from ongoing channel monitoring and consistency with applicable King County policies.
- **SED-4**—The Snoqualmie River gravel study should be completed and its findings made available for consideration of potential flood risk reduction actions. Similar approaches should be applied to other rivers in King County as appropriate.
- **SED-5**—Funding should be pursued for identifying and implementing alternatives to gravel removal that reduce or eliminate flood risk associated with channel sedimentation in a manner consistent with federal and state environmental mandates and salmon habitat recovery plan goals.

Figure 4-6

A SEDIMENT MONITORING PROGRAM AND ITS COMPONENTS

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG46.ai wgab **Data source:** Adapted from Kondolf et. al. (2001) Figure 44

4.3.2 Naturally Occurring Woody Debris Management

The selective alteration or removal of naturally occurring logs and logjams is a flood hazard management tool used for managing river channel conveyance and localized erosion hazards. While generally considered beneficial to river systems, large woody debris can cause localized hydraulic changes, such as a blockage or redirection of flow that in turn can increase the risk of flood-related damage. Flood-related risks that may be associated with woody debris accumulations include damage to bridge footings, embankment erosion, backwater flooding and channel avulsion. However, woody debris plays a significant role in the maintenance of natural riverine processes that are essential to the formation of fish and wildlife habitat and to the prevention of bank erosion and channel avulsions, so disturbance or alteration must be done judiciously.

Pacific Northwest rivers have historically contained large amounts of natural woody debris recruited through bank erosion, channel avulsion and wind throw. This woody debris has played a major role in channel forming and stabilizing processes, physical habitat formation, sediment and organic-matter storage and the formation of flood refuge habitat. However, during the 19th and 20th centuries, logging, navigational improvements and flood control efforts resulted in the removal of most of the large woody debris from Pacific Northwest rivers, including those in King County. The extent of debris removal and the methods used contributed to the degradation of fish and wildlife habitat, including habitat for species currently listed as threatened under the Endangered Species Act. Retaining large woody debris in local rivers is considered so vital to the recovery of threatened salmonids that installation of constructed log structures is frequently included as a major component of habitat restoration projects in local salmon habitat recovery plans and is often recommended as mitigation for habitat impacts resulting from human activities.

Until the late 1970s, King County commonly used its flood control authority to remove fallen trees from rivers as a means of reducing possible impediments to the conveyance of floodwaters. King County has abandoned these routine channel clearing practices due to increased competition for limited flood hazard management funds and the improved understanding of the function of large woody debris in riverine environments. While King County's approach to managing natural woody debris accumulations has changed dramatically, the River and Floodplain Management Program continues to receive calls requesting the removal of fallen trees or other debris from river channels.

Existing policy guidance directs King County to dislodge, cut, or remove naturally occurring large woody debris only where the material poses an imminent flood threat to public safety or infrastructure. Where action is deemed necessary, solutions that reduce the imminent flood risk with the least disturbance to woody debris are preferred. For example, minor repositioning or trimming of large woody debris so that it can remain in the channel or adjacent floodplain is preferred to removal of the wood from the riparian area. If the woody debris does not pose an imminent flood threat to a public facility or structure or to public safety, conditions are documented and monitored by the River and Floodplain Management Program staff. This approach is intended to address situations of flood threat while avoiding adverse impacts on the habitat of fish and wildlife.

Under current practice, River and Floodplain Management Program staff investigates each reported debris accumulation to determine the nature and degree of flood risk associated with it and to make recommendations consistent with the adopted woody debris management policies. As it is recognized that there may be non-flood-related public safety concerns, investigation findings are documented and the information is shared with the King County Sheriff's Office. The Sheriff's Office may choose to further investigate the reported debris accumulation and has legal authority to close a portion of the river to recreational use and passage until the risk is resolved.

Recommendations

- **WD-1**—The River and Floodplain Management Program should continue its current approach to woody debris management, which includes field investigations to evaluate potential flood-related risks associated with reported debris and, if necessary, action that is consistent with the *2006 King County Flood Hazard Management Plan* policies and all regulatory requirements.
- **WD-2**—The Department of Natural Resources and Parks should develop internal policies, protocols and procedures relating to naturally occurring large woody debris and other instream obstacles. The protocols, policies and procedures should describe how the department will respond to reports of newly fallen trees, drift logs, or logjams in river channels or on flood protection facilities. Development and implementation of these policies should be coordinated with other agencies and departments.
- **WD-3**—If funding becomes available, the River and Floodplain Management Program should take a more comprehensive approach to large woody debris management and conduct periodic surveys describing the location, character, and potential flood-related and river recreational risks associated with woody debris accumulations. This survey information should be posted on the River and Floodplain Management Program's web page at http://dnr.metrokc.gov/wlr/flood/Boaters/boaters.html, which already provides the locations of installed woody debris. Information on natural woody debris would be beneficial to habitat managers, recreational river users, and the King County Sheriff's Office.
- **WD-4**—The Department of Natural Resources and Parks should conduct a study to assess where and how much large woody debris is likely to accumulate over time in various river reaches and approaches to maximize its ecological value while minimizing its risk. The study would have two parts: 1) a before and after assessment of large woody debris accumulations, complaints and flood and safety risks since inception of the current practice and 2) construction of a large woody debris budget, that would identify source or recruitment areas, transport reaches, and deposition or accumulation areas of large woody debris, and would identify potential future ecological benefits and risks associated with large woody debris accumulations. The large woody debris budget should be used to determine how, when, where and under what conditions future large woody debris management would occur

4.3.3 Naturally Occurring Landslide Management

Along Puget Sound rivers, landslides can be of sufficient size to block or greatly impede river channel flow and result in flooding, bank erosion and channel migration. Where there is nearby development, these landslides can impact property and infrastructure and cause great concern for safety. However, the flooding, bank erosion and channel migration caused by landslides can be highly beneficial for river ecology. It can create new mainstem and side-channel habitats, scour and invigorate the condition of older channels and deliver gravel and large woody debris important for salmon spawning and overall fish and wildlife habitat diversity.

The traditional approach to managing landslide hazards has been to wait until a landslide has occurred or shown signs of movement, and then armor the base of the landslide at its interface with the river. Additionally, development is required to be set back from landslide areas with a slope of forty percent or greater and to direct runoff away from the unstable slope. In spite of these regulatory measures, landslides continue to occur along King County's major river systems due to development on or near steep slopes pre-dating current regulations or due to natural slumping and sliding of over-steepened slopes. However, attempts at landslide management have not addressed the impacts of major landslides on floodplain management in opposing or upstream and downstream areas and riverbanks. Furthermore, landslide management has not addressed the ecological impacts of preventing or limiting the extent of

landslides. For example, armoring limits the ability of the river to occasionally scour gravel and inhibits natural vegetation that can create higher quality banks than the rock-lined banks that are the common result of past efforts, thus degrading the habitat value of landslide-river interfaces.

Recommendations

- **LS-1**—King County should develop study methods and conduct a mapping study along King County's major rivers that identifies impact areas of existing and potential major landslides, assesses flood risks within the impact areas, and assesses the ecological benefits of the major landslides. This information should be used to develop a long-term strategy to minimize flood risks and maximize ecological benefits of landslides.
- **LS–2**—King County should revise flood hazard maps following a landslide or other significant geologic event that may change flood or channel migration conditions.

4.4 FLOOD PROTECTION FACILITIES

Prior to 1993, flood hazard management efforts in King County relied heavily on traditional constructed flood protection facilities to inhibit flooding, erosion and channel migration. Together, these flood protection facilities, which include rock-faced levees, revetments, overbank channels, pump stations and associated appurtenances (see Figure 4-7) may be viewed as King County's flood protection infrastructure. This flood protection infrastructure has paved the way for considerable economic development in flood hazard areas, but these areas will always face the potential risk that the flood protection facilities could be overwhelmed, resulting in serious flood damage or personal injury.

King County has constructed hundreds of these flood protection facilities, many built in the middle of the last century using design standards reflecting the understanding at the time of construction, and they require ongoing maintenance and repairs. Additionally, information about the impact of these flood protection facilities on threatened fish and wildlife habitat is now more widely understood, making habitat consideration imperative. Future management of the flood protection infrastructure will involve gaining a better understanding of the condition and performance of the flood protection facilities; conducting reach-scale risk-based assessments to help inform management decisions; retrofitting the flood protection facilities to improve long-term cost-effectiveness and compatibility with habitat recovery efforts; and modifying the land uses protected by these flood protection facilities to reduce flood risks.

4.4.1 Existing Flood Protection Facilities

The range of land uses occupying flood hazard areas in each river basin is reflected in the flood protection facilities characteristically found in that basin. A general description of each type of flood protection facility follows.

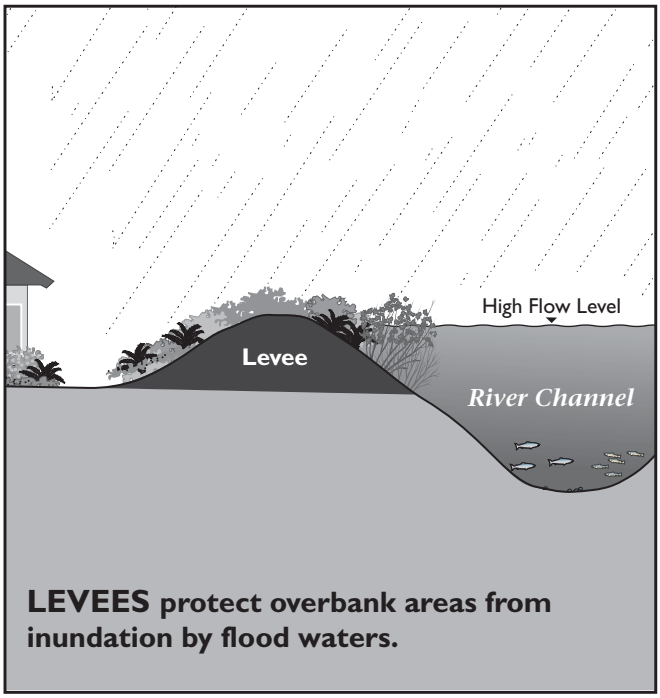
Levees

Levees are raised embankments built parallel to rivers to contain or direct flood flows even when river water surface elevations are greater than the elevation of the surrounding floodplain. Levees that are linked to high ground in a manner that excludes river water from the adjacent area are called "containment levees." Levees that are not tied to high ground and that primarily serve to prevent deep fast flows and potential channel migration through the area being protected are called "training levees." Figure 4-8 illustrates these two types of levees. Levees have traditionally been built immediately adjacent to the channel's edge, maximizing the landward area protected and available for developed uses. They are built wide enough, typically between 12 and 18 feet across the top, to allow vehicular access along their top for inspection and repair.

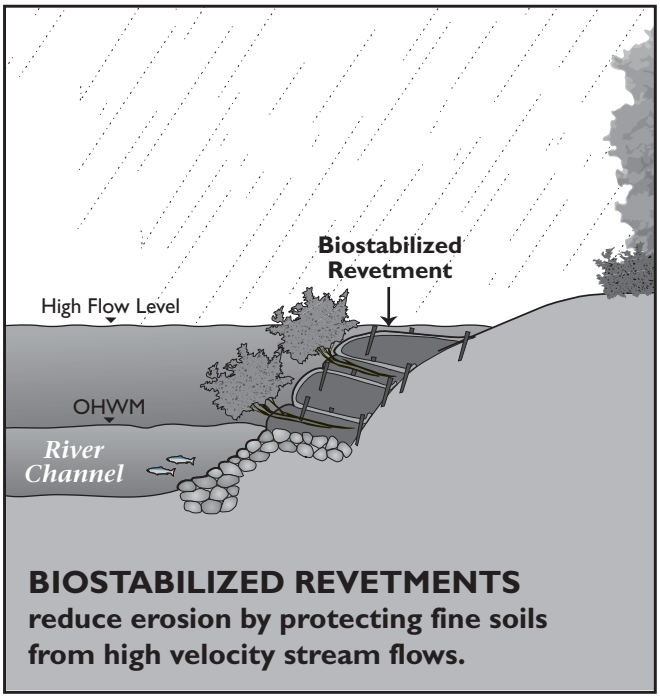
Figure 4-7

CAPITAL IMPROVEMENT PROJECTS BUILT OR MAINTAINED BY KING COUNTY FOR FLOOD CONTROL

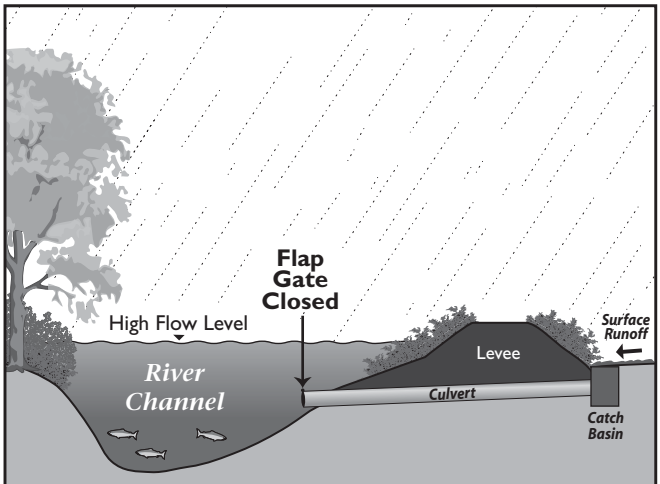
2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



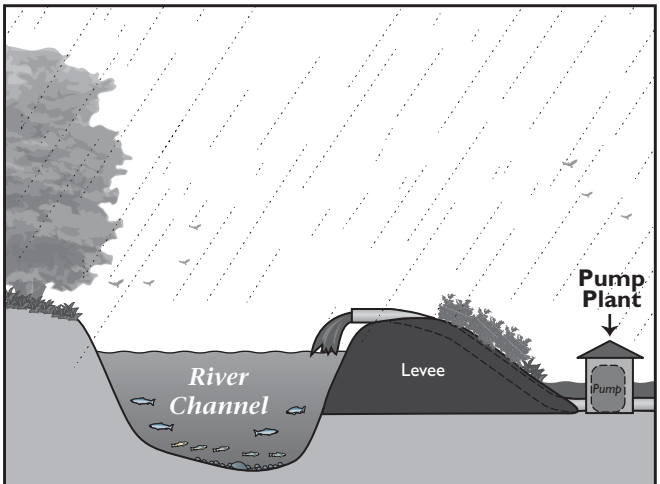
LEVEES protect overbank areas from inundation by flood waters.



BIOSTABILIZED REVETMENTS reduce erosion by protecting fine soils from high velocity stream flows.



FLAP GATES close during high river stage to prevent backward flow in culverts. During lower river stages, the flap gate is open to pass surface runoff through the levee and into the river.



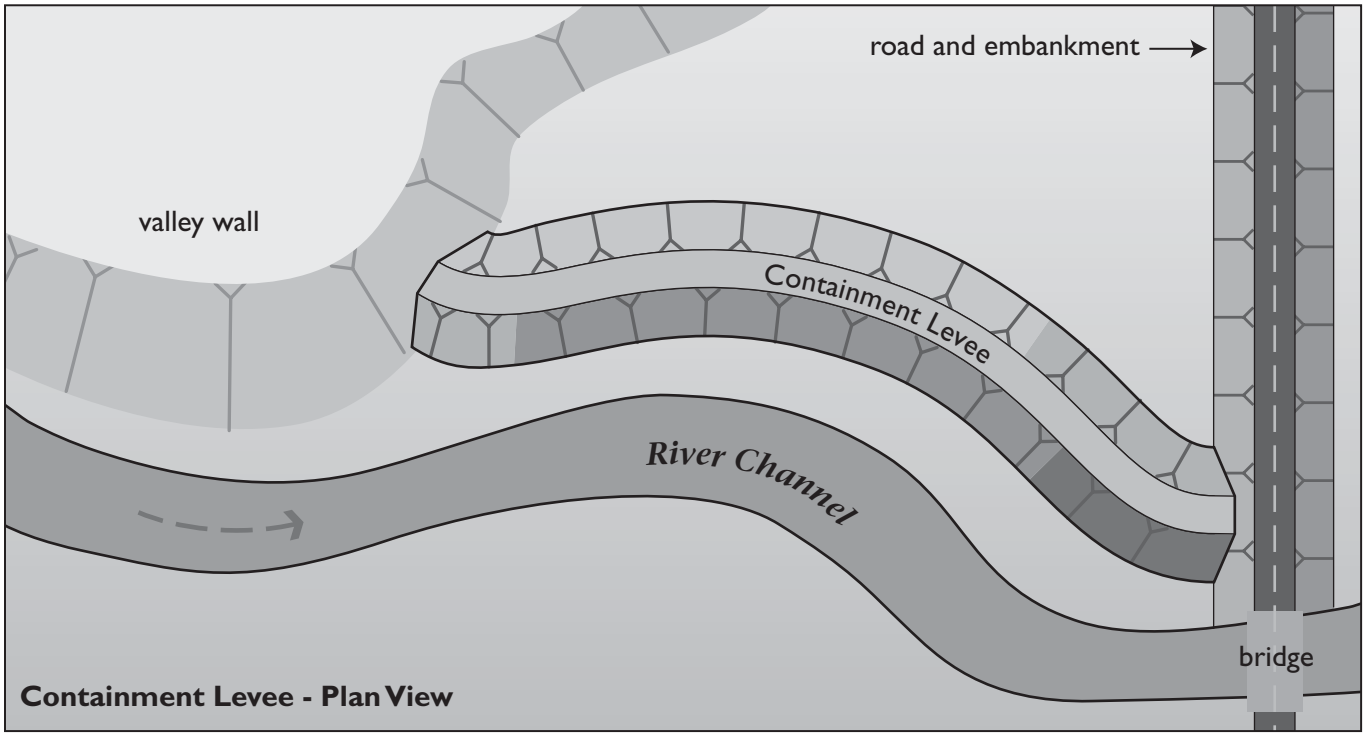
PUMP PLANTS lift water into rivers from the low ground behind levee systems.

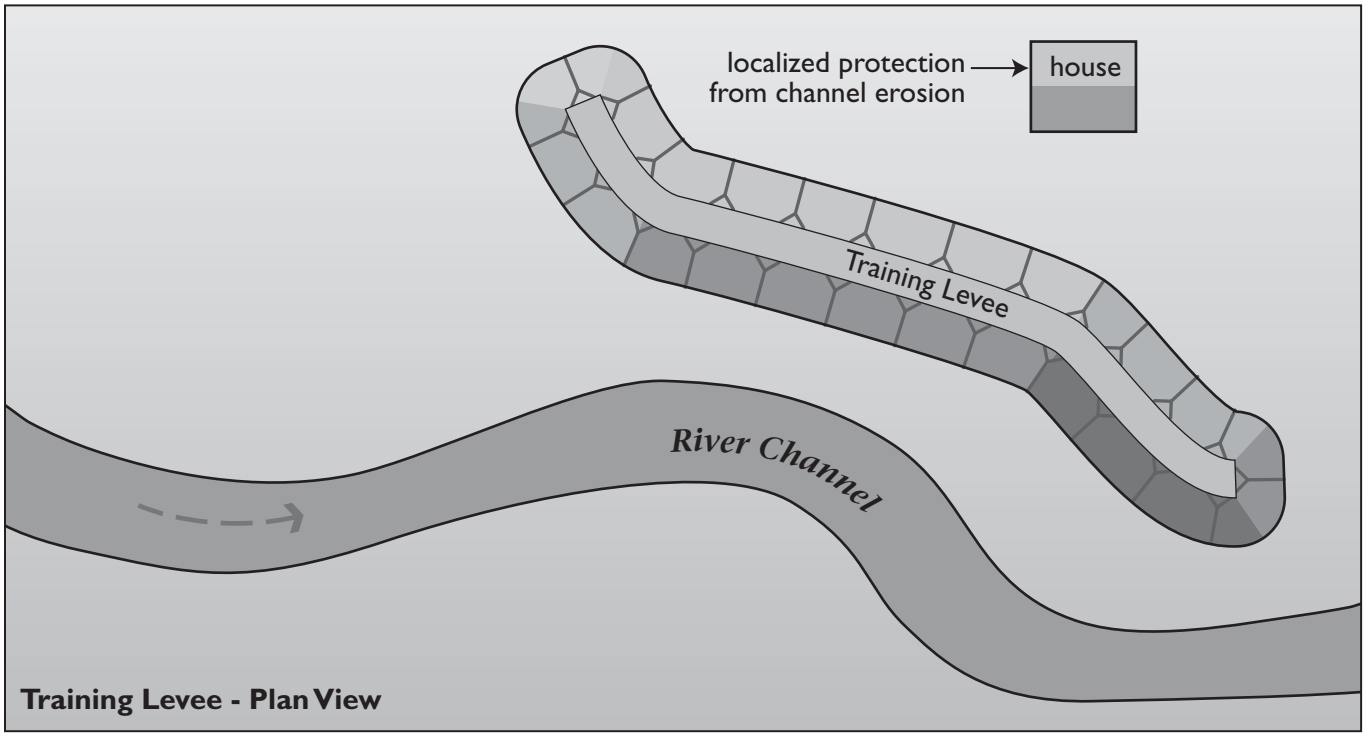
File name: 0604fhmpFIG47.ai wgab

Figure 4-8

CONTAINMENT AND TRAINING LEVEES

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN





File name: 0601fhmpFIG48.ai wgab

Levees in King County were generally built by creating a prism of native gravels and soils available from the site along the edge of the channel, and covering it with angular rock, typically referred to as riprap. This rock tended to be dumped rather than placed in an interlocking manner, leaving it susceptible to displacement. A levee's overall structural integrity is fundamental to its ability to contain or direct flood flows. Factors that affect a levee's strength and durability include bank steepness, surface stabilization and erosion control techniques, fill material and irregularities, and overall dimensions. Generally, a ratio of 2 feet horizontal run to 1 foot vertical rise (2H:1V) is the steepest slope considered stable, although this can vary somewhat depending on the soil composition. The U.S. Army Corps of Engineers general standard is a ratio of 2H:1V. On many levees in King County, the bank slopes are much steeper. The composition of the fill material and facing material for King County's flood protection facilities is not well known or documented, but most were constructed with a heavy or light loose riprap toe and a blanket of loose riprap as a facing material to protect the embankment from erosion and toe scour. Properly sized riprap can withstand high velocity flood flows, however, the original riprap material is generally undersized relative to the erosive potential of high velocity flows, and may be easily washed away. Due to these structural deficiencies, these older flood protection facilities have required extensive repair and maintenance, and studies and observations suggest that a large number of the levees remain at risk of failure. U.S. Army Corps of Engineers guidelines suggest that vegetation be cut to prevent the root system from penetrating the levee prism. In addition, the rock blanket on the face of the flood protection facilities inhibits development of healthy riparian vegetation that provides essential habitat for fish and wildlife.

King County lacks a set of uniform and contemporary standards for inspection, assessment, monitoring and maintenance, despite the need to improve the condition of these flood protection facilities. The U.S. Army Corps of Engineers promotes the use of a set of federal standards that dictate minimum levee dimensions with respect to containment and freeboard as well as removal of all vegetation greater than 2 inches in diameter from levee slopes. Levees that meet these thresholds, and are maintained in accordance with these standards, are eligible for damage repair assistance through the Rehabilitation and Inspection Program promulgated under Public Law 84-99. Under this program, the U.S. Army Corps of Engineers is authorized to fund and construct repairs to levees managed by local governments. However, many King County levees were built with inadequate freeboard to meet these requirements. Additionally, the federal standards for vegetation clearing do not accommodate the regional need for riparian vegetation essential to fish and wildlife habitat and recovery of endangered and threatened native species. The federal standards are therefore only applied to a small percentage of King County levees, leaving most ineligible for federal assistance if they are damaged.

Federal certification of levees, which is different from eligibility for damage repair assistance through the Rehabilitation and Inspection Program, is required to allow areas behind the levee to be mapped as outside the floodplain on Flood Insurance Rate Maps. Currently, very few levees within King County have been mapped as certified levees in Flood Insurance Rate Maps. If these levees were made to meet the federal certification standards, then there would be a greater level of safety and property protection afforded to the protected properties, and flood insurance in areas protected by these levees would be less costly or not required. However, the cost to upgrade the existing network of levees, some of which would require complete replacement, would be in the hundreds of millions of dollars. Given this extremely high cost, an assessment of the potential benefits would be necessary to determine the feasibility of repairing or constructing certified levees.

Revetments

Revetments are riverbank flood protection facilities that are designed to prevent bank erosion and lateral migration of the river channel. Unlike levees, revetments are not designed to contain floodwaters, but rather to maintain the course of the river. They may be built in locations that remain subject to flooding,

or even in high bank areas where flooding is not an issue. Many revetments in King County protect roads, bridges, trails, parks and other public infrastructure from being damaged or destroyed. King County maintained revetments also protect a substantial amount of private property from erosion and channel migration or avulsion.

Revetments have traditionally been built by covering the riverbank with a layer of riprap. As with the levees, the facing material, in many cases, is too small to withstand the erosive force of the river, the slopes are over-steepened, and they lack a well-anchored toe at the base of the slope. These deficiencies make these flood protection facilities highly susceptible to low bank erosion and slumping, requiring ongoing maintenance and repair. For revetments, there is even less of a prescribed standard for maintenance than levees, because revetments are not eligible for the Rehabilitation and Inspection Program available to qualified levees. As such, revetments are not subject to the U.S. Army Corps of Engineers standards for vegetation management. Since the two most common problems on these flood protection facilities is the need for improved bank stabilization and riparian vegetation, the maintenance objective for these flood protection facilities currently focuses on establishing diverse communities of native plants as a means of simultaneously increasing the structural integrity of the flood protection facilities and improving fish and wildlife habitat.

Pump Stations, Floodgates and Culverts

Pump stations, floodgates and culverts protect areas behind levees from ponding due to local drainage. They are conduits for draining local runoff landward of the levee into the river. In addition, pump stations and floodgates prevent river flows from backing up into protected floodplain areas when the river stage is high. These flood protection facilities all function as appurtenances to the levee system. Any levee modification or repair must address these structures as well.

Currently, King County operates three pump stations on the Green River. Two of these stations pump water that ponds landward of the levee system into the river. These pump stations, built by the U.S. Soil Conservation Service and operated and maintained by King County, have both exceeded their design life and are in need of renovation and upgrading. The third pump station pumps water from a seepage-interception system behind a levee back into the river.

Flap gates and check valves are flood-closure devices used on the riverward side of a culvert that runs through a levee prism to prevent the backflow of river water though the levee and into the protected area. When river stage is high, the pressure of the water against the device keeps it closed so that the river does not flow back through the culvert and flood the area behind the levee. However, proper operation of these floodgate devices is frequently impaired. On the riverward side, they are prone to being buried by sediments, which block the gate from opening to allow drainage to the river. Conversely, the gate sometimes becomes plugged with debris that prevents it from closing, which allows the flooded river to flow back into local drainage systems. King County has responded on several occasions to address problems with flapgate malfunctions during flooding events. In other instances, outdated and failing culverts have been identified and replaced. Many of the existing culverts are constructed with corrugated metal pipe, which has a limited functional life due to rusting problems. Other outfalls are constructed with jointed segments of reinforced concrete pipe, which can separate at the joints as riverbank slopes settle differentially, leading to both culvert failure and piping of materials from beneath the levee. Newer outfall systems are thoroughly reviewed by King County staff and required to comply with rigorous federal standards for drainage conduits passing through levees, including measures to address seepage, piping, settlement, and backup flood closure capability. The River and Floodplain Management Program currently lacks a complete inventory of existing flood protection facilities however, and there is no routine inspection schedule for them to support proper maintenance and operation.

In addition to concerns with flood management functions, culverts and floodgate devices may also raise fish passage concerns. While rarely an issue with outfalls serving municipal storm drainage system, culverts and floodgates are also employed in a number of locations where tributary streams enter the Green River through levees or road embankments. In these instances the ability of adult fish to pass upstream may be impaired or even prevented. Passage of juveniles into and out of tributaries may also be affected by such flood protection facilities. A failing culvert was recently removed from a local tributary channel joining the Green River at Mile 32.0 to address this type of problem, and the associated portion of the levee system was opened up to provide for fish passage at this location. Many other locations may exhibit similar problems, and retrofits at these locations are likely to be required. The September 9, 1989 *Green River Pump Operations Procedures Plan*, Section III.C.(2), requires that newly installed flood gates have backup closure systems, and the salmon habitat recovery plan for Water Resource Inventory Area 9, *Green/Duwamish and Central Puget Sound Watershed Salmon Habitat Plan: Making Our Watershed Fit for a King*, recommends that older flood gates be retrofitted for fish passage.

Instream Structures

Instream structures are typically constructed of a combination of large wood and rock elements embedded, anchored, tethered, or placed in the channel in order to modify hydraulic conditions. In some applications, these structures are designed to mimic naturally occurring logjams and are referred to as engineered or constructed log jams. In other approaches, log crib structures or clusters of log pilings may be used. Their presence in the channel forces flow around them and, depending on their placement, can deflect flows away from the bank to reduce scour or erosion, hinder or prevent channel avulsions, or create areas of scour (pools) or deposition (bars) that provide habitat diversity. King County has constructed a small number of these structures on the major rivers and is continuing to work with this technology. Most recently, permit agencies have discouraged the installation of rock riverward of the existing edge of water, preferring the use of wood as it might have existed naturally. Figure 4-9 illustrates how log structures may be used to protect unstable and eroding riverbanks.

Overbank Conveyance Channels

Overbank conveyance channels are typically created by enabling river flow to reoccupy preexisting or former secondary channels that were carved across the floodplain through years of historical flooding. They can function to lower the river's flood elevations and velocities through a reach. In King County, remnant overbank channels exist where historical flow paths were disconnected from the main channel by human activity, such as levee or revetment construction. However, their remnant topography largely still exists in the landscape and they can be reestablished as pathways to convey overbank flows. Overbank channels are generally created by the natural flow pattern and movement of the river over time, and are thus naturally well-suited to flow conveyance. However, they may also be constructed as newly created channels to provide a pathway for a portion of a river's flood flows. All these channels, whether historical or newly created, provide additional benefits by increasing the unique and highly valuable side-channel habitat used by salmonids for rearing and flood refuge. Very few overbank conveyance channels have been created or restored by King County, but as floodplain properties are acquired through home buyout and other programs, the opportunity to use this flood risk reduction tool should increase.

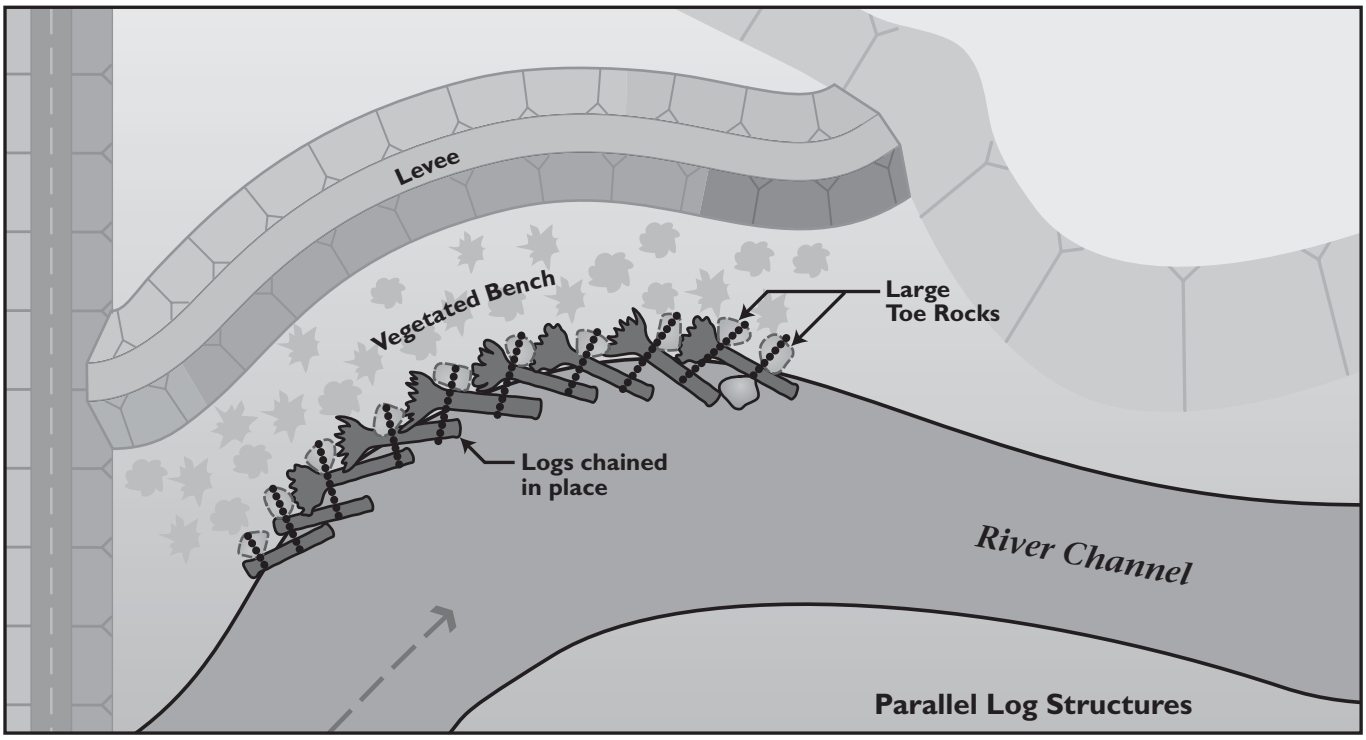
Sedimentation Basins

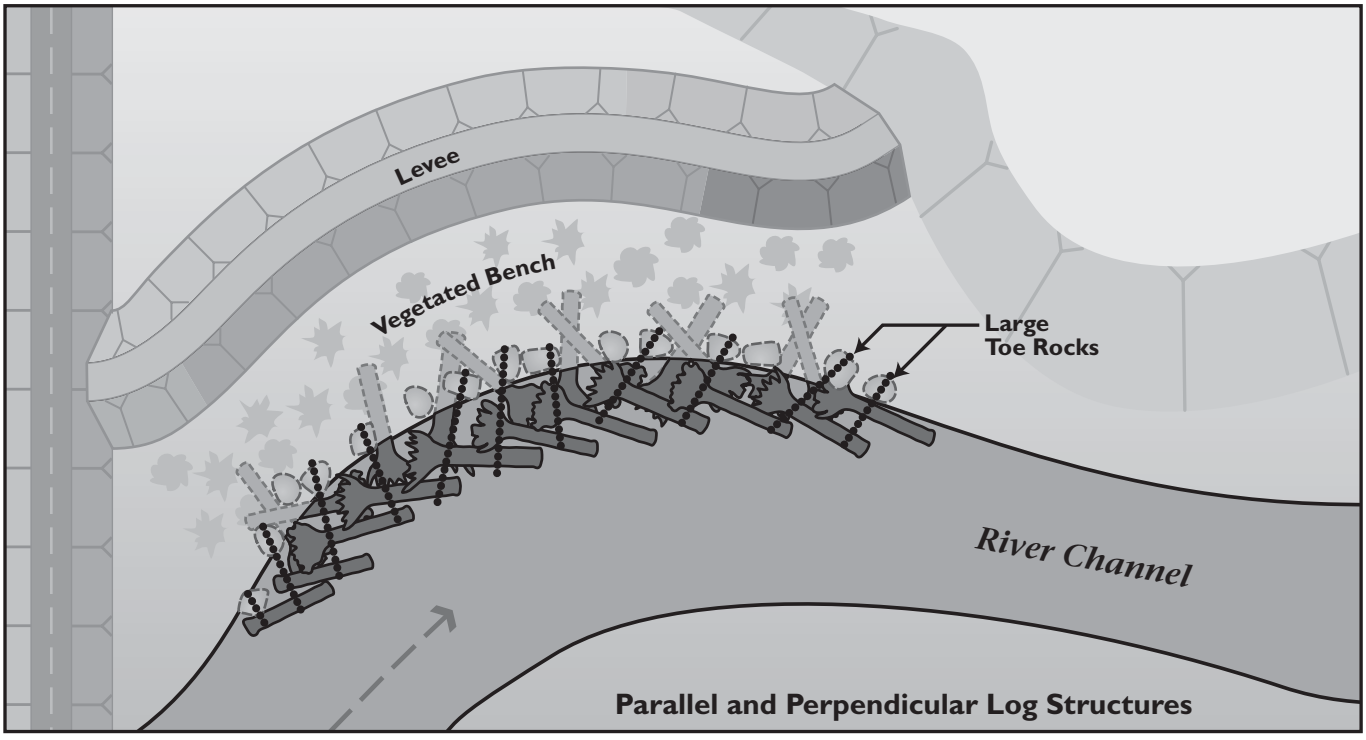
Sedimentation basins are artificial depressions dug into areas where sediment will be transported in order to trap the material that would otherwise be carried and deposited downstream. After a flood, or simply as periodic maintenance, the basin is cleaned out to make room for continuing sedimentation. King County currently operates a number of sedimentation basins as part of its urban drainage program, but to date, has not constructed any within the mainstem rivers or their major tributaries.

Figure 4-9

BIOSTABILIZED RIVERBANK WITH LOG STRUCTURES

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN





File name: 0604fhmpFIG49.ai wgab

4.4.2 Management Considerations

Flood protection facilities provide many important benefits, but they also have drawbacks in terms of their effect on flood-related risks and on fish and wildlife habitat. Future construction and repairs to the flood protection infrastructure will need to consider a number of important factors, with respect to functionality for flood hazard management as well as other beneficial river and floodplain uses.

Benefits and Equity of Existing Flood Protection Facilities

Construction and maintenance of flood protection facilities in King County has provided significant public safety and economic benefits to hundreds of homes, businesses, farms, roads, and bridges. These flood protection facilities have reduced the frequency of flooding and severity of erosion along miles of King County rivers. Protection of public infrastructure such as roads and bridges, which are often the only evacuation routes out of flood-prone areas, is a particularly important public safety function of these flood protection facilities. Containment of flood flows by levees has been translated into significant economic growth of protected areas by promoting development of historical floodplains, as exemplified by the industrial and commercial development lining the lower Green River. Additionally, while the costs of flood Protection facility construction and maintenance are borne by the public, the value to the economy is a regional benefit.

Risks Associated with Encouraging Floodplain Development

The presence of flood protection facilities may foster development in flood-prone areas that might otherwise be less hospitable to development. However, they only reduce the risks and cannot eliminate them. The risk always exists that a flood protection facility may be overwhelmed during an extreme flood event, even if a levee is federally certified. Most of the flood protection facilities in King County were not designed to withstand the 100-year flood. Even the few flood protection facilities that were previously assumed to be certified may not meet today's federal certification standards. Many King County-managed flood protection facilities were built nearly half a century ago and do not meet contemporary design standards. However, the presence of flood protection facilities can create a false sense of security among developers and property owners. This false sense of security can lead to a lack of awareness and use of other flood protection alternatives, such as obtaining flood insurance. When a levee is certified and landward areas are not mapped as a regulatory floodplain, flood insurance is not mandatory. This can have a devastating economic impact on financial resources in the event of a levee failure.

Cost-Effectiveness of Flood Protection Facility Construction, Maintenance and Repair

Due to the extensive number of existing flood protection facilities within King County's inventory, and the fact that many are nearing the end of their design life, ongoing maintenance uses a significant portion of the funds available for flood hazard management in King County. Maintenance includes minor and routine repairs as needed to maintain access, general performance and inspection capability. Maintenance also includes the more significant repairs made to flood protection facilities following damage caused by major flood events, but does not include replacement work. Flood protection facilities also can be gradually degraded by non-flood damage caused by off-road vehicle use, burrowing animals, rotting dead tree roots, aging culverts and outfall pipes and other penetrations through flood protection facilities, and sediment deposit, which can contribute to slumping.

Over the long term, the benefit provided by construction, maintenance and repair of a flood protection facility should outweigh the costs. Considerations of cost-effectiveness may include an assessment of flood protection facility conditions and functionality; assessment of the value of the assets protected and

the potential impacts on the regional economy; impacts on natural resources; legal obligations; and the feasibility of other alternatives.

Effects on Fish and Wildlife Habitat

Historical construction and maintenance techniques for levees and revetments tended to degrade natural riparian conditions and aquatic habitats for salmon and trout. The blanket of riprap that typically covers the river bank does not readily support native vegetation. Where vegetation does grow, it may be cut to facilitate inspection in accordance with the U.S. Army Corps of Engineers standards. Disturbed soils tend to promote the growth of non-native species such as reed canarygrass, Himalayan blackberries, and Japanese knotweed rather than desirable native plant communities. Levees and revetments have also eliminated numerous side channels and wetland areas by separating them from the main channel of the river. Side channels are important refuge areas for salmonids during high flows; they also provide sheltered rearing habitat for juvenile fish. Current salmon habitat recovery plans call for the reconnection or restoration of many of these off-channel habitat areas to the mainstem rivers and their major tributaries.

4.4.3 Management Alternatives

A wide range of alternatives are available for managing King County's flood protection facilities. King County should seek to construct, maintain, and repair flood protection facilities in a manner that maximizes flood risk reduction, cost-effectiveness and environmental benefits. The following actions can be used independently or in combination to achieve this goal.

Bioengineering

Along natural rivers, fallen trees lodge in the bed and banks of the channel and riparian vegetation lines the bank, helping to slow localized flow velocities while the roots help bind the soil. This reduces the potential for bank erosion and provides valuable riparian habitat features, including protective cover from predation, shade, and food. Bioengineering mimics this natural bank stabilization technique by incorporating live plants and large wood features into the fabric of the flood protection facility and as instream structures. Bioengineering takes advantage of the velocity dampening capabilities of riparian vegetation and installed large woody debris, and the cohesiveness of interlocking plant root structures to create riverbanks that are more stable than those armored with rock riprap and that can provide fish and wildlife habitat. Rather than deteriorating, these structures grow stronger over time. Using the *King County Guidelines for Bank Stabilization Projects* adopted as a component of the 1993 *Flood Hazard Reduction Plan*, King County has moved away from the almost exclusive use of rock riprap toward the use of bioengineering as the basis for nearly all repairs and retrofits on existing levees and revetments.

Toe Key Installation

One of the most common forms of bank failure along levees and revetments is caused by scour at the base of the slope, undermining the bank and causing the upper layers to collapse into the channel. Embedding larger rock into the channel bed and lowermost portion of the banks provides a stable toe key capable of supporting the overlying flood protection facility. Integrating large protruding wood and rock elements can further protect the bank by creating hydraulic roughness, which slows near-shore velocities, and providing valuable cover for habitat. A rock toe key built by interlocking large rock at the bottom of the slope results in a more stable toe than does the traditional method of dumping rock from a truck or placing it with a dragline.

Levee or Revetment Slope-Back or Bench-Back

Many levee and revetment slopes are over-steepened as a result of their original construction or subsequent damage and repair. Decreasing the steepness of the face, and for levees the back slope as

well, can greatly improve the stability of the structure and increase channel capacity. Given that placement of fill within the channel reduces the flood conveyance capacity of the channel and is generally prohibited, slope-back projects must be achieved by reducing the angle of the slope and widening the flood protection facility, which increases the landward footprint of the facility. For levees, the increased footprint can be dramatic since both front and back slopes are made flatter, often requiring additional right-of-way to be secured in fee or easement from property owners. Slope-back projects typically include the installation of new toe rock and large woody debris and the establishment of native plant communities. While slope-back levee retrofits can increase the stability of the structure, they do not provide as much opportunity for fish and wildlife habitat improvements as do bench-back retrofits, which are described below.

In some cases, the lower portion of a levee or revetment is repaired in place, while the upper part of the flood protection facility is set back. The toe may be rebuilt, but the existing toe alignment is retained. Between the toe and the set back upper bank is a bench, hence the name "bench-back." Bench-back projects typically result in the creation of a flat or gently sloping area between the upper bank and the toe, which can be planted with native vegetation, including large trees which are discourage or prohibited on levee slopes. Bench-back projects result in increased channel capacity, more stable slope angles, reduced near-bank velocities and accompanying erosion, and a net improvement in riparian and aquatic habitats. Bench-back levee retrofits can also result in slow water refuge for fish during floods. As with other projects that involve moving a flood protection facility landward, acquisition of additional right-of-way in fee or easement may be needed.

Levee or Revetment Setback Projects

Levee and revetment setback projects involve removing an older flood protection facility and reconstructing it some distance from the edge of the river bank using updated techniques. Since a levee contains the river within the channel up to a given flow level, a levee setback can open up the previous cut-off floodplain for reoccupation by inundation and conveyance. Allowing flows to spread out across the floodplain dramatically increases conveyance capacity and surface roughness, lowering floodwater velocities and elevations through the reach. This reduces the potential for flood damage to the new levee. In addition, depending on the hydraulic conditions of the project site, the flood benefits of the setback may extend beyond the boundaries of the project itself. Figure 4-10 shows typical levee setbacks.

A revetment setback is similar to a levee setback, but rather than increasing the frequency and extent of inundation, it increases the ability for the river to migrate across the floodplain, carve new alignments, or create and occupy side-channels. The setback revetment establishes a new barrier to erosion some distance landward of the original revetment alignment, and might be constructed as a feature that is buried underground. A revetment setback is often accompanied by excavation to remove fill placed within the footprint of the original revetment and adjacent floodplain and may result in increased channel capacity.

Both levee and revetment setbacks provide a means for the partial reestablishment of natural river processes essential to healthy riparian ecosystems and provide habitat elements that are valuable to fish and wildlife. Levee setbacks are generally consistent with recommendations in salmon habitat recovery plans.

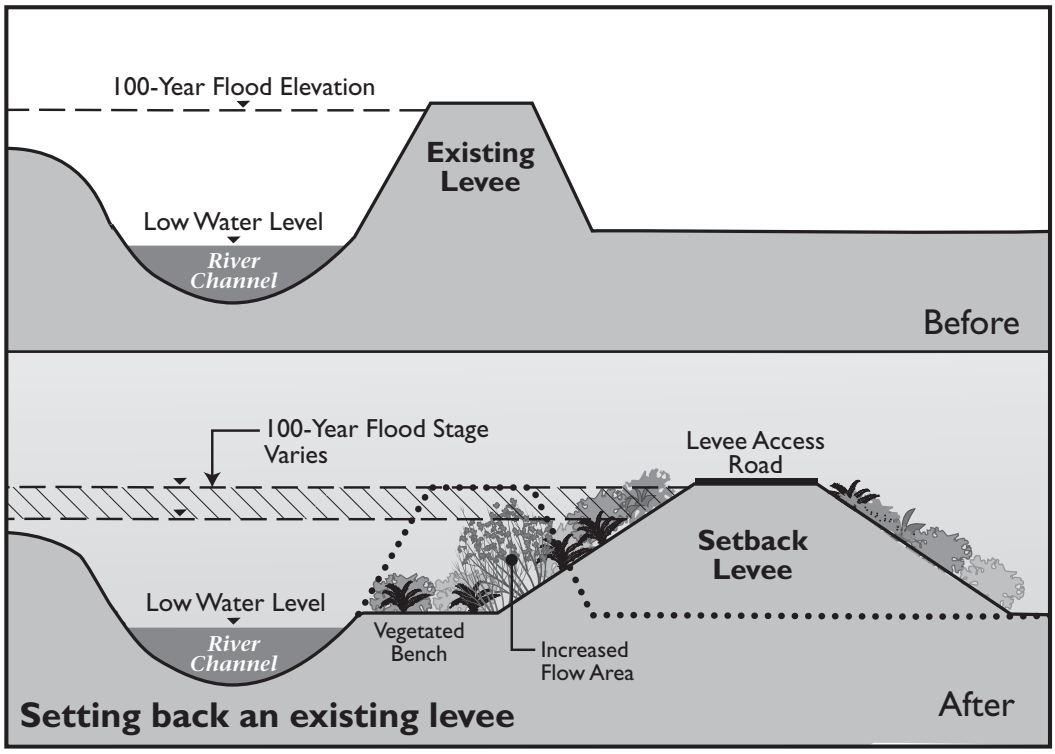
Levee and Revetment Removal

As a result of land use changes, or reduced flood risk following completion of one or more flood hazard management activities in the vicinity, a portion of King County's levees and revetments may no longer be needed. In locations where a flood protection facility has become obsolete, the complete removal of that facility may be useful to help alleviate flooding risks up and downstream and to assist in restoration of historical fish and wildlife habitat. Removal can be done on all or just a portion of a facility.

Figure 4-10

LEVEE SETBACK PROJECTS

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG410.ai wgab

Flood Protection facility removal projects will commonly be designed in coordination with other flood hazard management activities as part of an overall strategy for a river segment. Design considerations include an evaluation of the existing condition of the flood protection facility, comparison of flood risks with and without the facility, and analysis of alternatives for mitigating those risks. At a minimum, flood protection facility removal projects involve excavation of fill and bank armoring material and stabilization of the project site using native vegetation. Further, restoration of the site for fish and wildlife or other flood-compatible uses can be coordinated with appropriate departments and agencies. The benefits typically include increased conveyance capacity, lower flood elevations and velocities, reduced flood risks, reconnection of the river with its floodplain, reintroduction of natural river processes, lower maintenance costs, and improved habitat for fish and wildlife.

New or Expanded Levees and Revetments

New levee and revetment construction is limited due to the cost, regulatory constraints, potential for exacerbating flood risks on neighboring properties, and likely adverse impact on habitat and other natural resource values. However, it remains a tool that may be employed in certain situations of high flood risk and limited alternatives. In these instances, the design of the flood protection facility should be based on bioengineered bank stabilization techniques, include slope angles that are stable for the materials used, and to the maximum extent practicable, provide some level of set back from the existing channel. If designed as a setback project, the construction may be able to occur entirely out of the wetted area of the channel.

Raising or widening a levee or extending a levee or revetment lengthwise has many of the same drawbacks and challenges as new construction. It creates additional limits on conveyance and storage of flood flows, reduces natural river processes, impairs habitat conditions, and undergoes rigorous permit requirements. New or expanded levees and revetments are generally inconsistent with salmon habitat recovery plans. There are limited applications where these activities may be warranted. Widening a levee can improve its strength and resilience or improve access for vehicles performing inspection and maintenance. Increasing levee height can also increase the level of protection. Like levee slope improvements, height and width increases almost always require landward expansion of the flood protection facility footprint and additional right-of-way.

Floodplain and Channel Modifications

Reconnection or creation of overbank conveyance channels may require excavation at the inlet or along the channel in order to successfully convey flows at the desired flood threshold. In some cases, opening up access at the upstream end may be accomplished in concert with a levee or revetment removal project.

Instream modification could involve excavation of material encroaching on the channel or installation of features to improve flow patterns and channel complexity. In areas of regular and predictable sedimentation, construction of an off-channel sediment basin may be a valuable alternative to gravel removal and the environmental degradation that can accompany it. The basin would be sized and located to capture materials that would otherwise deposit in the channel and would need to be maintained on a regular schedule in order to preserve its sediment-trapping functions. Alternatively, large woody debris that historically was deposited naturally in the river may need to be installed where volumes of wood are lacking.

4.4.4 Easements

The River and Floodplain Management Program has over 1,000 river protection easements, which have been acquired for flood protection facility construction and maintenance. River protection easements typically coincide with flood protection facility locations; however numerous easements exist in locations

where facilities were never constructed. River Protection Easements grant King County access across private property for flood protection facility maintenance and management purposes and for channel monitoring surveys.

The rights granted through river protection easements are variable, but most grant King County rights to a strip of land 30 feet wide running parallel to the river along the top to the riverbank. This arbitrary width is generally sufficient for routine maintenance and minor repair work, but is seldom sufficient for the reconstruction of flood protection facilities in a manner consistent with current standards and practices. In addition, the 30-foot width does not always connect to legal access routes to the riverbank. Easements for reconstruction purposes must provide sufficient room for construction access benches, flood protection facility setbacks, biotechnical bank stabilization features, and riparian vegetation. In addition, property owners have encroached upon many of the easement areas with temporary or permanent improvements. These features hinder routine inspection and emergency vehicle access and can increase the cost of repair and reconstruction. Figure 4-11 illustrates how current easements are not sufficient to meet slope and levee access design needs for flood protection facility repairs.

Another shortcoming of most of the existing easements is the lack of explicit language allowing King County to establish native plant communities along the face of flood protection facilities. While establishment of such communities has become a standard permit requirement for virtually all types of flood protection facility repair and retrofit projects, there is little King County can do to prevent property owners or other parties from cutting or removing the vegetation that is integral to the project.

New River Protection Easement language has been developed that addresses the position of the easement relative to the river channel, necessary easement widths, and the updated rights and authorities granted to King County through the easement. This remedy will only apply to newly acquired easement rights. For most existing easements, only the acquisition of a new or revised easement will address these concerns. King County should pursue new or revised easements on a case-by case basis, through negotiations with affected property owners, wherever King County intends to perform major maintenance or rehabilitation of older levees and existing easements are inadequate for the project.

4.4.5 Inventory, Inspection, Assessment and Monitoring

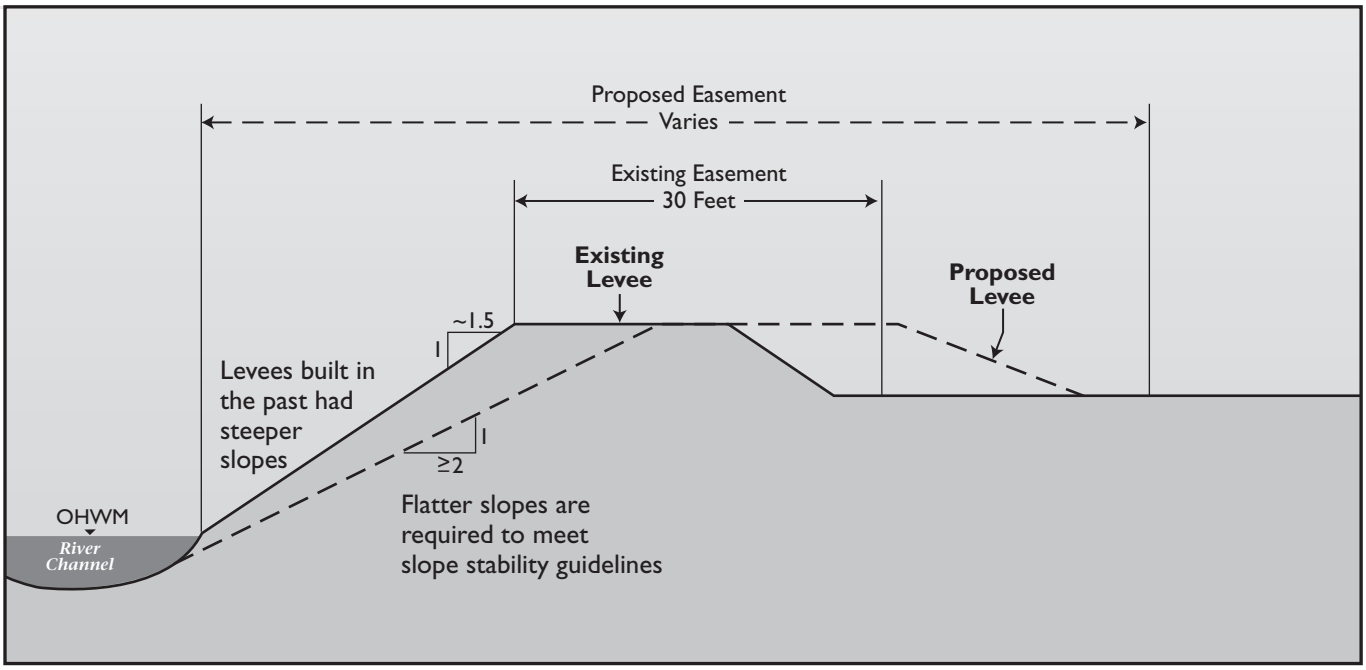
King County's inventory of levees and revetments is currently a listing of flood protection facility information that only identifies flood protection facility locations and includes minimal information about the characteristics of each facility. A partially complete but detailed easement database has also been developed. The current inventory does not contain information on monitoring, inspection, follow-up assessments, or maintenance, nor does it contain enough detailed information about the flood protection facilities' condition, flood risks, or potential actions that can be taken to make them more compatible with salmon habitat recovery plans.

Flood protection facility inspections are typically conducted during summer low-flow periods or immediately following major flood events to identify and characterize damage and potential risks. Flood protection facility inspections are used to identify and characterize damage and potential problems, while condition assessment utilizes inspection information to identify the condition of the facility and any potential risks associated with its current condition. Condition assessment following a flood protection facility inspection may include gathering data to evaluate the facility's condition. Except during federally declared disasters, when FEMA provides a uniform format for quantifying damage, flood protection facility inspection and assessment data collection and storage methods are not standardized. In addition, due to the large number of flood protection facilities and competing priorities for flood hazard management resources, regular inspections have not been conducted for a substantial part of King County's flood protection infrastructure.

Figure 4-11

LARGER EASEMENT AREA NEEDED FOR MAJOR LEVEE REPAIRS

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN



File name: 0604fhmpFIG411.ai wgab

Monitoring activities are flood protection facility inspection and assessments that are conducted for a specific purpose. Monitoring activities include post-construction or post-repair flood protection facility monitoring, and flood event monitoring. Following completion of a flood protection facility repair or reconstruction project, monitoring is used to determine how well the project is working and to provide information that can be used to inform future design and construction practices. Post-construction monitoring is typically a required element of certain types of project permits. Flood monitoring is performed during flood events to actively monitor the condition of flood protection facilities in order to identify and prevent potential failures or emergency conditions. Flood event monitoring follows fairly well established protocols. However, post-project monitoring varies dramatically from project to project. Protocols for the collection and analysis of post-project monitoring data should be standardized to more directly inform future project design decisions.

While the current level of effort for collecting and tracking flood protection facility conditions have been adequate given the very limited repair and retrofit budget, a more systematic approach will be needed to meet the increasing maintenance and repair needs of these aging flood protection facilities. Currently, information on the condition of King County's flood protection facilities from past inspections, assessments, and monitoring is stored in a variety of formats, including monitoring reports, field notes and institutional knowledge of the River and Floodplain Management Program staff. Strategies for managing these flood protection facilities will need to identify and prioritize actions that may involve changes to the facility design, changes to the land uses protected, or both. To develop these strategies, the River and Floodplain Management Program will need to first develop a comprehensive understanding of the current condition of all flood protection facilities managed by the program. The program should then use this information to evaluate the potential risk of failure of these flood protection facilities and the subsequent risk to public safety, infrastructure, private structures, and the regional economy.

Standardization of the inventory, inspection, assessment and monitoring processes would be beneficial in creating a consistent set of baseline information for all levees, revetments and associated structures managed by the River and Floodplain Management Program. Regular inspections should be expanded to account for all flood protection facilities managed by the River and Floodplain Management Program, and a protocol for identifying obsolete facilities should be developed. In addition, the current flood protection facilities inventory should be expanded into a centralized flood protection facilities inventory database. A centralized flood protection facilities inventory database would be a multi-purpose management tool, and would ideally have the following capabilities:

- Provide floodplain managers with a comprehensive source of current information on all flood protection facilities managed by the River and Floodplain Management Program and provide user-friendly tools necessary to view, sort and compare data records.
- Store characteristic information on each flood protection facility, including but not limited to information that can be used to characterize physical, geographic and geomorphic aspects of each facility; and store maintenance, damage, repair, inspection, and monitoring records.
- Use state-of-the-art technologies, and provide secure and easy access to flood protection facility records for multiple users.
- Assist in scheduling and tracking routine flood protection facility inspections, monitoring, and maintenance.

The inventory would also be a resource to direct future flood protection facility repairs or retrofits that could also be readily shared with other agencies proposing actions in and around King County's flood protection facilities.

4.4.6 Summary

The flood protection infrastructure provides vital protection to people and existing development, including other public infrastructure, commercial hubs, and numerous communities and private residences. However, the existing set of flood protection facilities is extensive and in many places outdated, requiring maintenance and improvements in excess of available resources. This leaves many of the areas presumed to be protected by the flood protection facilities vulnerable to flood hazards. Strategies for managing these flood protection facilities will need to identify and prioritize actions that may involve changes to the flood protection facility design, changes in land uses, or both. Site-specific choices will need to reflect a long-term outlook and should be made within the context of the flood hazard management corridor. Such an approach will significantly reduce flood-related risks and flood hazard management costs and support beneficial uses of river corridors.

4.4.7 Recommendations

- **INFRA-1**—The River and Floodplain Management Program should manage its flood protection infrastructure in a manner that supports the creation of low-risk, high value aquatic habitat. Projects to construct, maintain, repair, or retrofit a flood protection facility should be designed within the context of the cumulative impacts of the action, and should reflect a cost-effective approach to reducing flood risks and improving appropriate beneficial uses.
- **INFRA-2**—The River and Floodplain Management Program should take the following actions to ensure that risks associated with the flood protection facilities it manages are identified and corrected, and resources allocated to meet future maintenance, repair and project needs:
  - Develop standardized approaches for inspection, assessment and post-project monitoring of King County's flood protection facilities.
  - Develop protocols and procedures for identifying obsolete flood protection facilities and for decommissioning obsolete facilities where appropriate.
  - Develop a user-friendly and more complete flood protection facility inventory database to store information on flood protection facilities.
  - Implement a flood protection facility inventory and assessment program to develop baseline data for all flood protection facilities managed by the River and Floodplain Management Program.
  - Develop and implement a routine inspection program for all flood protection facilities managed by the River and Floodplain Management Program.
  - Using a risk-based approach at a river-reach scale, evaluate the potential risk of failure of flood protection facilities and the subsequent flood damage risk to public safety, infrastructure, private structures, and the regional economy.
- **INFRA-3**—Consideration and selection of site-specific actions should not be controlled by previous choices made at a given location. The River and Floodplain Management Program should continue to explore new and innovative approaches to reducing flood-related risks and improving aquatic and riparian habitats, including the use of instream log structures, overbank channels and other more innovative types of flood protection facilities.
- **INFRA-4**—The River and Floodplain Management Program should conduct a systematic inventory of pump stations, flood gates and culverts penetrating levee systems to determine the location and condition of these flood protection facilities. These flood protection facilities should also be assessed to determine if they present a barrier to fish passage.

- **INFRA-5**—New easements should be acquired as needed to construct, maintain, repair, relocate or retrofit flood protection facilities, including flood containment levees and revetments. Existing easements should be reviewed on a case-by case basis for their adequacy whenever King County undertakes major maintenance, repair, relocation, or retrofit of existing levees and revetments, and new or revised easements sufficient for these purposes should be acquired from the current property owners wherever the existing easement is found to be deficient.
- **INFRA-6**—The River and Floodplain Management Program should maximize funding opportunities through federal, state and local grant application submittals to implement flood risk reduction actions.

4.5 FLOOD HAZARD EDUCATION AND FLOOD PREPAREDNESS, FLOOD WARNING, AND EMERGENCY RESPONSE

Given the amount of development that has already occurred within flood hazard areas, floods will continue to impact people and property indefinitely. In order to help minimize these impacts, the River and Floodplain Management Program has established three programs to help citizens and jurisdictions prepare for and respond to floods: the Flood Hazard Education and Flood Preparedness Program; the Flood Warning Program; and the Emergency Response Program.

4.5.1 Flood Hazard Education and Flood Preparedness Program

The King County Flood Hazard Education and Flood Preparedness Program is designed to increase awareness of locally available resources and information to help citizens prepare for flood events and prevent, minimize, and recover from flood damage. Flood hazard education is an important and low-cost tool that can be used to increase public safety and reduce flood risks.

King County Flood Hazard Information Services

The Water and Land Resources Division of King County's Department of Natural Resources and Parks, the Building Services Division of the Department of Development and Environmental Services, and the Road Services Division of the Department of Transportation have trained staff who respond to citizens' flood-related inquiries. The Building Services Division provides information about Flood Insurance Rate Maps, interprets local flood hazard regulations, and reviews parcel-specific flood hazard studies. The Water and Land Resources Division shares data and observations on current and historical flood conditions, provides information about flood hazard reduction programs and projects, and offers technical expertise on the major river systems in King County, including development of numerous hydraulic models and maps. The Road Services Division staff are available 24 hours a day, seven days a week, to assist citizens with flooding on road right-of-ways in King County.

Annual Public Information Strategy Meetings

King County holds an annual public information program strategy meeting to assess the current flood-related public outreach activities designed to increase the public's awareness of locally available resources and information that they can use to prevent or minimize, prepare for, and recover from flood damage. This meeting is also used to explore new ideas for the Flood Hazard Education and Flood Preparedness Program. Information gathered at this meeting is used to determine which flood preparedness activities should be continued and to develop proposals to enhance the program. This meeting also meets the requirements of the National Flood Insurance Program's Community Rating System Activity 330.

Annual Agency Meetings

King County holds annual multi-agency meetings in four locations in King County near the beginning of the flood season to coordinate flood response activities and procedures and to update priority call lists that are used for early flood notification. First response agencies attend these meetings, including King County's Office of Emergency Management, dam operations staff from the City of Seattle and the U.S. Army Corps of Engineers, fire and police departments, the Red Cross, adjacent counties and participating cities, King County Roads Maintenance staff, the National Weather Service and local school districts. In the White River Watershed, a number of private citizens are also invited to these meetings.

Brochures

King County publishes and distributes a Flood Warning Information brochure each year. This brochure describes local flood hazards, highlights the services available through the Flood Warning and Emergency Response programs, makes recommendations for flood insurance and personal preparedness, and lists important phone numbers for information and assistance. The brochure includes a map of the major rivers that shows the locations and key historical flood data for flood warning gages. The brochure also includes the link to King County's flood web site. This brochure is mailed to approximately 4,680 property owners located in the riverine floodplains in King County, and is distributed through local libraries and through many cities having jurisdiction within these floodplain areas.

Annual Outreach to Repetitive Loss Properties and Floodplain Residents

Each year, King County mails an informational letter and the Flood Warning Information brochure to all owners of repetitive loss properties and owners of floodplain properties located in unincorporated areas of King County, as identified by the FEMA through the Flood Insurance Rate Maps. Currently, King County sends these letters to identified repetitive loss properties, all of which are located within an identified 100-year floodplain. A basin-specific repetitive loss area analysis that illustrates the location and characteristics of each repetitive loss area is included in Appendix C. These mailings make property owners and residents aware of the flood hazards likely to affect their property, highlights programs and projects available to them to help reduce flood-related risks, describes steps they can take to protect themselves and reduce flood damage, and provides contact numbers for more information.

Annual Flood Awareness Month

Each fall as flood season approaches, King County promotes increased public awareness and preparedness through a media campaign. The campaign is frequently kicked off with an official Executive Proclamation designating the last week in October as Flood Awareness Week. This campaign typically includes a press release to local television, radio, and print media to help focus attention on flood and winter storm hazards. The campaign encourages citizens to become familiar with expected local flood conditions near their home and work locations and to prepare in advance of an emergency.

In addition, King County partners with the City of Seattle and Washington State Department of Transportation in an extensive public information campaign called "Taking Winter by Storm." The campaign includes a web site and paid advertising on radio and television as well as a major news conference that has received wide media coverage. The "Taking Winter by Storm" web site, which at the time of this printing was located at http://www.govlink.org/storm/default.asp, hosts breaking news, storm reports, transportation alerts, and links to all-hazards planning, flood preparedness and emergency response information.

Notice on Title

Homebuyers are made aware of the flood hazards associated with properties located in the floodplain through a Notice on Title that is required to be recorded by the property owner on the title instruments when a development permit has been approved by King County. The Notice on Title alerts future buyers that the property is located within a flood hazard area and that the property and structures may be inaccessible by emergency vehicles during flood events.

Internet Web Site

King County has developed an Internet web site dedicated to flooding topics. This site, which at the time of this printing, was located at http://dnr.metrokc.gov/topics/flooding/FLDtopic.htm, has extensive and detailed information about local flooding conditions, the *2006 King County Flood Hazard Management Plan*, flood warning and emergency response, floodplain and channel migration hazard mapping, King County's flood protection facilities and home buyout and elevation programs. An online mapping application is available to assist in determining whether properties are within a 100-year floodplain, a channel migration zone or other hazard areas. The web site also has links to other sites with valuable flood-related information, including:

- The King County Office of Emergency Management, which coordinates regional emergency response efforts.
- The U.S. Geological Survey site, which contains real-time gage data.
- The National Weather Service site, which provides forecasts and predictions.
- The American Red Cross, which gives instructions for preparing disaster supply kits.
- The U.S. Army Corps of Engineers site, which contains sandbagging instructions.
- The FEMA National Flood Insurance Program site, which provides a variety of information on flood maps and hazard mitigation.
- King County Roads Services Division, which provides information on road closures.

Flood hazard map information is also accessible though the iMap web page maintained by King County's Department of Development and Environmental Services. The iMap web address is http://www.metrokc.gov/gis/mapportal/iMAP_main.htm.

Department of Development and Environmental Services Customer Information Bulletins

The Department of Development and Environmental Services publishes a number of brochures describing special conditions and limitations related to development in the floodplain, flood risk reduction, flood hazard determinations and insurance. These documents are available to the public online and at the walk-in self-help counter, on request through inquiries, or from staff assisting in the review of development applications.

Public Libraries

King County public libraries carry a number of flood-related documents for checkout and reference, including at least one full set of FEMA's *King County Flood Insurance Study* and *Flood Insurance Rate Maps for King County*; the 1993 *King County Flood Hazard Reduction Plan*, and the current *2006 King County Flood Hazard Management Plan*, as well as a number of individual basin plans. Some libraries also offer free copies of the flood information brochures.

Recommendations

- **PREP-1**—King County should prepare flood preparedness and warning information for display in home improvement stores.
- **PREP-2**—King County should provide greater outreach to the real estate community, particularly the Multiple Listing Service.
- **PREP-3**—King County should promote flood preparedness and flood warning in public and private schools.
- **PREP-4**—King County should improve access, maneuverability, and content of flood preparedness and flood risk reduction information on the King County Web site.
- **PREP-5**—King County should update the flood preparedness segment of the King County Office of Emergency Management television production series called "Project Impact."

4.5.2 Flood Warning Program

The Flood Warning Program is responsible for the collection and dissemination of near-real-time flood information and forecasts in a manner that allows individuals and organizations to prepare for developing flood conditions and take appropriate actions to minimize flood damage. The Flood Warning Program's operational document is the *Flood Warning Instruction Book*, which is updated annually and includes contact information, operating procedures, and information on King County's network of flood protection facilities. The Flood Warning Program makes use of an integrated network of data collection hardware and software, data interpretation tools and communications equipment to provide high quality information essential to public safety before and during flood events. Currently, the Flood Warning Program provides services to both unincorporated and incorporated areas, primarily along the Snoqualmie, Tolt, Cedar, Green and White Rivers and Issaquah Creek.

Flood Warning Center

The Flood Warning Center is the center of operations for the Flood Warning Program during flood events. The Flood Emergency Director activates the Flood Warning Center whenever one or more rivers reach Phase II of the four-phase flow-based flood warning alert system illustrated in Figure 4-12. River and Floodplain Management Program staff tracks river conditions as part of their normal workday duties. Outside regular business hours, and on weekends, these efforts are augmented by the Roads Services Division, which operates a year-round, 24-hour dispatch center and monitors river gage data for the Flood Warning Program.

The Flood Emergency Director may choose to open the Flood Warning Center in response to indications of heavy rainfall, flood watch bulletins issued by the National Weather Service, information from the U.S. Army Corps of Engineers or Seattle Public Utilities regarding dam operations, significantly damaged flood protection facilities, or reported river obstructions. The Flood Warning Center is also activated following a significant seismic event in the region (5.5 or greater magnitude) to coordinate inspection of flood protection facilities and to check with dam operators to determine the safety status of their facilities.

The Flood Warning Center issues public warnings when rivers rise above specific flow thresholds. These warnings are issued to police, fire departments, schools, cities, first response agencies, and in some cases, the general public through volunteer phone trees. Flood Warning Center staff are also available to citizens, agencies and organizations to answer questions and help interpret gage readings during a flood event. The Flood Warning Center also distributes flood information through a dedicated phone message system. The Flood Warning Center works with King County public information officers, who issue press releases frequently during flood events and work with other local media sources to provide accurate flood information to the public. These press releases are posted on the King County web site.

Figure 4-12

KING COUNTY FLOOD WARNING PHASE THRESHOLD AND FLOOD PEAK SUMMARY

2006 KING COUNTY FLOOD HAZARD MANAGEMENT PLAN

Phase	Tolt River (near Carnation)	Snoqualmie (Sum of Forks)	Issaquah Creek (near Hobart)	Cedar River (Landsburg)	Green River (Auburn)	White River (near Buckley)
I	1,500 cfs	6,000 cfs	200 cfs	1,000 cfs	5,000 cfs	2,500 cfs (Unless COE or NWS calls with specific info)
II	2,500 cfs	12,000 cfs	500 cfs	2,800 cfs	7,000 cfs	6,000 cfs
III	4,500 cfs	20,000 cfs	800 cfs	3,500 cfs	9,000 cfs	8,000 cfs
IV	7,000 cfs	38,000 cfs	1,000 cfs	4,200 cfs	12,000 cfs	12,000 cfs

RECENT LARGE FLOOD PEAKS

Tolt River (near Carnation)	Snoqualmie (Sum of Forks)	Issaquah Creek (near Hobart)	Cedar River (Landsburg)	Green River (Auburn)	White River (near Buckley)
11,200 cfs 11/24/90	50,100 cfs 11/24/90	1,360 cfs 11/24/90	10,800 cfs 11/24/90	11,500 cfs 11/24/90	14,100 cfs 1/9/90
11,400 cfs 11/29/95	49,350 cfs 11/29/95	1,240 cfs 2/8/96	6,580 cfs 11/30/95	12,400 cfs 2/8/96	13,200 cfs 12/1/95
11,800 cfs 12/15/99	44,400 cfs 2/8/96	1,190 cfs 11/14/01	5,870 cfs 2/10/96	11,200 cfs[1] 1/11/06	10,000 cfs[2] 1/11/06

[1] Provisional data subject to revision by United States Geological Survey

[2] Based on U.S. Army Corps of Engineers data on flow releases from Mud Mountain Dam for January 5-26, 2006 flood event.

File name: 0604fhmpFIG61.ai wgab

At Phase III or greater, or at the Flood Emergency Director's discretion, field inspection teams are sent out by the Flood Warning Center to monitor flood protection facilities and investigate potential flood risks. Significant information about flood conditions observed in the field, such as road and flood protection facility damage or overtopping, are reported back to the Flood Warning Center to be shared with the public and emergency responders.

Coordination With Other Agencies

During a typical flood event, the King County Office of Emergency Management activates the King County Regional Communications and Emergency Coordination Center when any river system reaches a Phase III threshold and is moving toward the Phase IV threshold. The Regional Communications and Emergency Coordination Center's role is to assist in procuring resources and coordinating flood-related and other emergency response activities in unincorporated King County, and to assist cities and special purpose districts within King County during emergencies if resources are available. A critical role of the Regional Communications and Emergency Coordination Center is the coordination of event-specific Emergency Management Teams made up of representatives from agencies and organizations whose services may be needed as flood conditions develop. Procedures for coordinating with the Regional Communications and Emergency Coordination Center are documented in the *Flood Warning Instruction Book.*

The Flood Warning Program works closely with the Roads Services Division and other agencies to obtain and share up-to-date information about major flood risks, road closures, evacuations, and other emergency services. Coordination also occurs with the U.S. Army Corps of Engineers and Seattle Water Department regarding dam operations.

Flood Data Collection

The U.S. Geological Survey, the U.S. Army Corps of Engineers and the National Weather Service operate a network of automated gages that collect flow and water elevation data on rivers and their major tributaries throughout King County. The raw data are transmitted via satellite to ground stations for processing and evaluation. Most of the gages used for flood warning are owned and operated by the U.S. Geological Survey; however, King County provides a substantial share of the annual maintenance, operation, and capital improvement program for this river gage network through a joint funding agreement.

Flood Warning Data Management System

King County's Flood Warning Center relies on a variety of tools to collect, analyze and distribute flood warning information. New technologies are incorporated when shown to improve efficiency and effectiveness. However, data management has not kept pace with other improvements. In some cases, data is managed and stored in the same manner as when the Flood Warning Program began over 40 years ago.

Efforts have been made to integrate many of the Flood Warning Center's functions. For example, Flood Warning Center staff use a customized software application to semi-automatically extract data from U.S. Geological Survey gages, and manually input other flood warning information. The application has analytical tools and is able to format data into standard reports that are used and distributed by the Flood Warning Center. While this new application has improved efficiency, it cannot be easily modified to include additional capabilities.

A web-based data management application has also been developed that automatically extracts U.S. Geological Survey or the U.S. Army Corps of Engineers gage data into a database and displays it on

several flood warning web sites. The web sites are actively used by the public, with over 20,000 visits being registered during January 2006. The web application has been designed for expansion into an integrated data management system allowing automatic or manual collection and analysis of data to help identify phase changes and provide notification of changing flood conditions.

Flood Forecasting

King County's current ability to provide flood flow forecasts is limited. Flow measurements taken in the upstream portions of a watershed are used by flow forecasters to generate short-term predictions for downstream areas. By comparing the relationships between conditions at the upstream and downstream locations during previous flood events, the travel time of a flood peak can be roughly estimated. However, because both the weather and the river systems are dynamic, each flood is different. Weather variations include the timing and intensity of precipitation, the temperature and snow level, the wind speed and direction, and the storm cell's location, speed, and direction of travel. River system variations include local factors such as log jams, bank erosion, landslide and gravel bar formation, as well as upstream flow control factors, such as dam operations. Antecedent conditions, which include previous rain and snow pack conditions, also affect the amount and timing of storm runoff. Because these dynamic variations influence the relationships between flood conditions at different locations, any predictive use of those relationships will always include a degree of uncertainty.

The National Weather Service's River Forecasting Center in Portland, Oregon issues short-term predictions of flows on rivers in Washington, Oregon, Idaho, and western Montana. These short-term flow predictions are based on two computer models: the National Weather Service River Forecast System and the Streamflow Simulation and Reservoir Regulation. Each of these models simulates soil, snow, stream channel and reservoir conditions in order to estimate resulting river flow conditions. Daily forecasts are made using observations of temperature and precipitation. Forecast of meteorological parameters are included in the river forecast model. These National Weather Service predictions are issued for several forecast points in King County, including Middle Fork Snoqualmie River near Tanner, North Fork Snoqualmie near Snoqualmie Falls, South Fork Snoqualmie River near Garcia, Snoqualmie River at Snoqualmie Falls and at Carnation, Tolt River near Carnation, Cedar River at Landsburg and Renton, Green River at Auburn, White River near Buckley and Issaquah Creek near Issaquah.

The Seattle office of the National Weather Service provides additional forecast detail when flooding is likely, and throughout flood events, with flood watch and flood warning statements. While the National Weather Service forecast information is valuable and widely used, an additional independent model would be beneficial. A model designed specifically for King County and adjacent watersheds would improve the ability of Flood Warning Center staff to interpret incoming gage and National Weather Service data, and to give meaningful forecasts to others.

Recommendations

- **WARN-1**—The Flood Warning Program should annually review, refine and document criteria concerning activities of the Flood Warning Center. The Program should include regular debriefings after flood events to incorporate flood warning responses and lessons learned into improved operating procedures and better flood warning services.
- **WARN-2**—The Flood Warning Program should evaluate commercially available flood threat recognition and notification systems and consider purchasing or developing a system that can directly send emails or pager notifications to first response agencies and citizens when river levels rise over specified thresholds.
- **WARN-3**—The Flood Warning Program should consider contracting services that use meteorological and hydrologic data to provide river flow and timing forecasts at different

points on King County major rivers. This additional source of flood forecast data will provide predictive information on the severity of flooding in areas of inundation.

- **WARN-4**—The Flood Warning Program should coordinate with King County Emergency Management to update and enhance the King County Emergency Management Plan so that there is linkage between the response actions of that Plan and those recommended by the *Flood Warning Instruction Book.*

4.5.3 Emergency Response Program

While flood emergencies may exist with or without a formal emergency declaration, disaster declaration, or proclamation of a state of emergency, flood emergencies at the county, state and federal level increase the availability of funding and material resources needed to lessen or avoid flood damage. The King County Executive may proclaim a state of emergency under the authority in K.C.C. 12.52.030. When a state of emergency has been proclaimed, local resources, such as staff and equipment, become available for emergency response. The King County Emergency Coordination Center is the lead on managing these resources.

The Governor of Washington State has the authority under RCW 38.52.050 to proclaim a state of emergency state-wide or for a specific community, depending on the severity and location of the emergency conditions. Generally, state resources are committed to the normal operations of state government, but by proclaiming a state of emergency, the Governor is authorized to use state resources that are otherwise not available under normal conditions.

The President of the United States is authorized to make a presidential emergency declaration or a presidential major disaster declaration. While no presidential emergencies have been declared in King County, 14 presidential major disaster declarations related to flooding have been made since 1956. A presidential emergency declaration provides only limited assistance; a presidential major disaster declaration authorizes a wide range of programs for recovery, including financial assistance to public agencies, loans for individuals, families and small businesses, loans for farmers and ranchers, financial assistance grants, and housing grants. Major disaster assistance is provided through regional FEMA centers and the state.

Planning Flood Emergency Response Actions

Sudden, unpredictable changes in river conditions, damage to critical flood protection facilities, or a lack of preparedness by those occupying the flood hazard management corridor, especially in flood-prone areas, can result in the need for emergency response actions. Actions that King County may take or assist with to help minimize flood damage include:

- Inspecting flood protection facilities to identify damage during and after major flood events
- Repairing damaged flood protection facilities that, because of the actual or potential consequences of their failure, must be repaired as emergency actions before or during a flood event, or soon after floodwaters have receded
- Providing information to flood response agencies engaged in flood fighting and evacuations
- Making flood and flood fighting information and flood fighting materials available to individuals and groups actively involved in flood fighting.

Currently, there are dam safety and emergency response plans for the City of Seattle's dams on the Tolt and Cedar Rivers, the U.S. Army Corps of Engineers' dams on the Green and White Rivers and the Snohomish PUD Culmback Dam on the Sultan River, which would affect the lower Snoqualmie River in

a dam break scenario. Puget Sound Energy has prepared an Emergency Operations Plan and conducts an annual emergency drill for the levee system on Lake Tapps, which would affect the White and Puyallup Rivers if a levee failure occurred.

Precautions that citizens can take to avoid or reduce flood emergency damage and risk include: evacuation, avoiding flooded roads, moving possessions and livestock to higher elevations, and building temporary sandbag walls to keep floodwaters out of homes and structures.

Emergency Repairs to Flood Protection Facilities

King County deploys patrol teams to monitor river conditions during flood events. The primary emphasis for these patrols is to monitor levee system performance, but they also monitor conditions at other locations, sometimes in response to citizen complaints. Patrol teams are trained to recognize situations that warrant emergency action to preserve levee system function or otherwise reduce flood risk. Prior to taking emergency actions, consultation with King County senior ecologist staff should be conducted to formulate the emergency response alternatives and preferred approach that would carefully minimize impact on aquatic and riparian habitat. When emergency repairs impact aquatic areas protected under the King County Critical Areas Ordinance or habitat for federally listed species, King County may be required to mitigate these impacts later.

Recommendations

- **RESP-1**—The River and Floodplain Management Program should monitor flood protection facilities during flood events, with special emphasis on high-flow conditions along containment levee systems. In addition, as time permits, King County should monitor flood conditions in other locations, including areas that have no existing flood protection facilities but have other at-risk structures.
- **RESP-2**—The River and Floodplain Management Program should take emergency action to reduce flood risk when such action is a high priority in accordance with Policy G-2, the action can be completed safely with a reasonable certainty of success, and all necessary resources including budget authority are sufficient.
- **RESP-3**—The River and Floodplain Management Program should develop general flood emergency response guidelines and site-specific emergency response plans for flood protection facilities maintained by King County.
- **RESP-4**—The River and Floodplain Management Program should coordinate with other agencies that have roles in response to flood emergencies.
- **RESP-5**—The River and Floodplain Management Program should conduct drills in which flood emergency scenarios are simulated and all parties likely to be involved in flood emergency response measures are involved to ensure that participating parties are kept up to date on changing laws and standards that may affect emergency response activities.
- **RESP-6**—The River and Floodplain Management Program should conduct emergency flood response activities in accordance with statutory notification requirements, including notification to the National Oceanic and Atmospheric Administration and U.S. Fish and Wildlife Service.